Appendix G: Climate impacts and adaptation actions for American black bear

Figure G.1. American black bear.

The Washington-British Columbia Transboundary Climate-Connectivity Project engaged science-management partnerships to identify potential climate impacts on wildlife habitat connectivity and adaptation actions for addressing these impacts in the transboundary region of Washington and British Columbia.[i] Project partners focused their assessment on a suite of case study species, vegetation systems, and regions chosen for their shared priority status among project partners, representation of diverse habitat types and climate sensitivities, and data availability. This appendix describes potential climate impacts and adaptation actions identified for the American black bear (*Ursus americanus*).

The black bear is a wide-ranging carnivore with relatively high sensitivity to habitat fragmentation.[2] In the transboundary region of Washington and British Columbia, the black bear's primary forest habitat exhibits relatively high connectivity.[2] Across the broader landscape, however, barriers to black bear movement are presented by both natural factors (e.g., dry, low-elevation habitat types; rivers) and human factors (e.g., urban areas, roads), with significant barriers present along major highways and the Okanagan Valley (Appendix G.1).[2]

Future climate change may present additional challenges and needs for black bear habitat connectivity.[3-4] First, climate change may impact black bear core habitat and dispersal corridors in ways that may make them more or less permeable to movement. Second, existing black bear core habitat and corridors may be distributed on the landscape in ways that make them more or less able to accommodate climate-driven shifts in black bear distributions. For such reasons, connectivity enhancement has become the most frequently recommended climate adaptation strategy for biodiversity conservation.[5] However, little work has been done to translate this broad strategy into specific, on-the-ground actions. Furthermore, to our knowledge, no previous work has identified specific climate impacts or adaptation responses for black bear habitat connectivity. To address these needs, we describe here a novel effort to identify and address potential climate impacts on black bear habitat connectivity in the transboundary region of Washington and British Columbia.

Potential climate impacts on habitat connectivity

To identify potential climate impacts on transboundary black bear habitat connectivity, project partners created a conceptual model that identifies the key landscape features and processes expected to influence black bear habitat connectivity, which of those are expected to be influenced by climate, and how (Appendix G.2). Simplifying complex ecological systems in such a way can make it easier to identify specific climate impacts and adaptation actions. For this reason, conceptual models have been promoted as useful adaptation tools, and have been applied in a variety of other systems.[6] The black bear conceptual model was developed using peer-reviewed articles and reports, project participant expertise, and review by species experts. That said, the resulting model is intentionally simplified, and

[i] This report is Appendix G of the Washington-British Columbia Transboundary Climate-Connectivity Project; for more information about the project's rationale, partners, methods, and results, see Krosby et al. (2016).[1]

should not be interpreted to represent a comprehensive assessment of the full suite of landscape features and processes contributing to black bear habitat connectivity.

Project participants used conceptual models in conjunction with maps of projected future changes in species distributions, vegetation communities, and relevant climate variables to identify potential impacts on black bear connectivity. Because a key project goal was to increase practitioner partners' capacity to access, interpret, and apply existing climate and connectivity models to their decision-making, project partners relied on a few primary datasets that are freely available, span all or part of the transboundary region, and reflect the expertise of project science partners. These sources include habitat connectivity models produced by the Washington Connected Landscapes Project,[2,7] future climate projections from the Integrated Scenarios of the Pacific Northwest Environment[8] and the Pacific Climate Impacts Consortium's Regional Analysis Tool,[9] and models of projected range shifts and vegetation change from the Pacific Northwest Climate Change Vulnerability Assessment.[10]

Key impacts on transboundary black bear habitat connectivity identified via this approach include changes in areas of black bear climatic suitability, changes in forest habitat, changes in disturbance regimes, and declines in the amount and duration of snowpack.

Changes in areas of climatic suitability

Climate change may impact black bear habitat connectivity by changing the extent and location of areas of climatic suitability for black bear; this may render some existing core habitat areas and corridors unsuitable for black bear, and/or create new areas of suitability. Climatic niche models provide estimates of species' current and projected future areas of climatic suitability, and are available for the black bear for the 2080s based on two CMIP3 Global Circulation Models (GCMs) (CGCM3.1(T47) and UKMO-HadCM3[ii]) under the A2 (high) carbon emissions scenario[iii] (Appendix G.3).

For both climate models, projections for the 2080s show a decline in black bear climatic suitability in river valleys, and the Okanagan Valley in particular. While these areas are currently in predominantly shrub-steppe vegetation cover, and are thus unlikely to provide significant black bear habitat, corridors crossing these valleys (especially the Okanagan) may currently be important for maintaining connectivity among black bear populations at higher elevations. Projected declines in climatic suitability in valleys suggest that valley crossings by black bears may become more difficult in the future, further isolating higher elevation populations separated by valleys. This loss of climatically suitable habitat is projected to be more widespread for the UKMO-HadCM3 than the CGCM3.1(T47) model. Despite potential loss of suitability in valleys, large areas of climatic suitability remain for the 2080s for both models, with some higher elevation locations in the Coast Range and Rocky Mountains seeing an increase in climatic suitability.

[ii] CGCM3.1(T47) and UKMO-HadCM3 are two Global Circulation Models (GCMs) which each project different potential future climate scenarios. The UKMO-HadCM3 model projects a much hotter and drier summer, while the CGCM3.1(T47) projects greater precipitation increases in spring, summer and fall. For these reasons, the UKMO-HadCM3 could be considered a "hot-dry" future, while the CGCM3.1(T47) could be considered a "warm-wet" future within the Pacific Northwest.

[iii] Emissions scenarios were developed by climate modeling centers for use in modeling global and regional climate-related effects. A2 is a high, "business as usual" scenario in which emissions of greenhouse gases continue to rise until the end of the 21st century, and atmospheric CO_2 concentrations more than triple by 2100 relative to pre-industrial levels.

Changes in forest habitat

Black bears utilize a variety of habitat types, but are predominantly associated with forest habitats. Changes in the distribution and quality of forest habitats in the transboundary region could therefore be expected to affect black bear habitat connectivity.

Two types of models are available that estimate future changes in vegetation for the transboundary region: climatic niche models and mechanistic models (Appendix G.4).[iv] Both types of models are based on results from two CMIP3 Global Circulation Models (GCMs): CGCM3.1(T47) and UKMO-HadCM3.[ii] Both models also use the A2 (high) emissions scenario.[iii] Climatic niche models project the persistence or slight expansion of shrub steppe and grassland habitats in the Okanagan Valley and other low elevation habitats (Appendix G.4). An expansion of shrub steppe vegetation into currently forested habitats could result in loss of core black bear habitat and a decline in the quality of dispersal corridors, reducing black bear habitat connectivity. However, mechanistic models project forest expansion into the Okanagan Valley (Appendix G.4). Such an expansion of forest habitat would increase core black bear habitat and the quality of dispersal corridors across low elevation valleys, enhancing black bear habitat connectivity. These conflicting results suggest that while climatically the Okanagan Valley and other lowland regions are projected to remain suitable for shrub steppe vegetation, changes in other ecological processes could favor forest; for example, increasing concentrations of carbon dioxide (CO_2) can increase the water use efficiency of trees, allowing forests to colonize areas that were previously too dry. This discrepancy helps to highlight the uncertainty inherent in how vegetation may react to changing climate conditions in these areas, and the difficulty in anticipating associated impacts on connectivity.

Changes in disturbance regimes

Climate change may affect black bear habitat connectivity by increasing the frequency and severity of summer drought (Appendix G.6: Water Deficit, July-September; Soil Moisture, July-September; Dry Spell Duration), increasing the risk of wildfires (Appendix G.6: Days with High Fire Risk), and influencing pest and pathogen dynamics (Appendix G.5: Probability of Mountain Pine Beetle Survival). Drier conditions could reduce the amount and/or quality of moist habitats and forests. A longer fire season and increase in area burned could also affect forest habitat.[11] Moisture stress and fire can increase tree mortality and bark beetle outbreaks, which can further increase the chances of large, high-intensity fires. In Washington State, probability of mountain pine beetle survival is projected to decline at lower elevations, but to increase at high elevations (Appendix G.5). Such disturbance events could affect black bear connectivity by reducing the amount and/or quality of available core forest habitat and movement corridors.

Declining amount and duration of snowpack

Projected declines in the amount and duration of snowpack (Appendix G.6: Spring (April 1st) Snowpack; Snow Season Length) may affect black bear habitat connectivity by allowing people earlier access to forest habitat for recreational use and timber harvesting and thinning. Earlier recreational use in forest

---

[iv] Climatic niche vegetation models mathematically define the climatic conditions within a given vegetation type's current distribution and then project where on the landscape those conditions are expected to occur in the future. These models do not incorporate other important factors that determine vegetation such as soil suitability, dispersal, competition, and fire. In contrast, mechanistic vegetation models do incorporate these ecological processes as well as projected climate changes and potential effects of carbon dioxide fertilization. However, mechanistic models only projected changes to very general vegetation types such as cold forest, shrub steppe, or grassland.

habitat could result in more human-bear interactions that could affect black bear core habitat quality and movement. It is unclear whether black bears may alter their denning behavior in response to climate change, but if food resources are available for more of the year due to an increase in the length of the growing season (Appendix G.6: Growing Season Length),[12] bears may spend less time in their dens, which may also lead to more human-bear interactions that may impact bear movement. Declines in snowpack amount and duration could also make it harder to set prescribed fires to reduce wildfire risks.

Adaptation responses

After identifying potential climate impacts on black bear connectivity, project participants used conceptual models to identify which relevant landscape features or processes could be affected by management activities, and subsequently what actions could be taken to address projected climate impacts (Appendix G.2). Key adaptation actions identified by this approach fall under three main categories: those that address potential climate impacts on black bear habitat connectivity, those that address novel habitat connectivity needs for promoting climate-induced shifts in black bear distributions, and those that identify spatial priorities for implementation.

Addressing climate impacts on black bear habitat connectivity

Actions to address the potential for valley bottom crossings to become more difficult as low elevation valleys become warmer and drier include:

- Identifying and protecting corridors and resources (e.g., wetlands or other water sources) likely to facilitate bear movement across low elevation valleys, in order to maintain connectivity among high elevation core habitat areas. Habitat connectivity models (Appendix G.1) could be used to evaluate low-elevation corridors for key areas where continued permeability will be especially important to maintaining broader connectivity, and which should thus be high priorities for connectivity conservation efforts.
- Focusing habitat retention efforts on riparian and wetland habitats; black bears frequently utilize these for dispersal through dry habitats, which may become less permeable to black bear movement as climate warms.
- Monitoring low-elevation corridors for vegetation changes that may affect black bear connectivity. If shrub steppe vegetation appears to be expanding, cross-valley corridors may become longer, making them less attractive to dispersing bears. Conversely, if forest expands into the valley, corridor suitability may increase for black bears. Monitoring would allow timely modification of connectivity conservation efforts to account for these or other possible changes.

Actions to address the potential for climate change to impact connectivity through more frequent and severe wildfires include:

- Using prescribed burns and thinning to reduce the risk of catastrophic wildfires and pest outbreaks that could negatively impact black bear core habitat areas and corridors. Consider engaging traditional ecological knowledge to help guide implementation, referencing the forest and grazing practices of First Nations and tribes to identify traditional strategies for managing fire risk and other potential climate impacts. In developed areas, implementing a new prescribed burn program would require careful evaluation of associated risks and benefits.

- Incorporating projections and observations of changes in the length of the snow season, evapotranspiration (Appendix G.6: Evapotranspiration, July-September), soil moisture deficits, and the timing of precipitation to inform the timing of fire prevention techniques as conditions change, in order to maximize their safety and effectiveness.
- Prioritizing implementation within existing black bear corridors (Appendix G.1), to ensure that critical linkages are not lost to severe fires.

Actions to address the potential for climate change to impact connectivity through increased potential for human-bear interactions due to declines in snowpack duration include:

- Managing road access and all-terrain-vehicle activity within black bear core habitat areas and corridors during sensitive times of the year, such as when bears emerge from hibernation or young bears disperse in the spring and early summer.
- Monitoring black bear denning, foraging, and dispersal behavior to identify and respond to increased human-bear interactions stemming from changes in the timing and location of bear movements.
- Monitoring recreation levels within black bear core habitat areas and corridors to identify and address changes that may negatively affect habitat connectivity.

Enhancing connectivity to facilitate range shifts

Actions that may help the black bear adjust its geographic distribution to track shifts in its areas of climatic suitability include:

- Maintaining and restoring corridors between areas of declining climatic suitability for black bear and areas of stability or increasing suitability (Appendix G.3).
- Maintaining and restoring corridors that span elevation gradients (e.g., climate-gradient corridors,[7] Appendix G.1), to ensure that black bears have the ability to disperse into cooler, higher elevation habitats as the climate warms.
- Planning the placement, orientation, and shape of reserve patches to maximize connectivity, span climatic gradients, and cross low-elevation valleys. As part of this, ensure that when clear cuts are made in forested black bear core habitat and corridors, reserve patches are connected with corridors.
- Focusing habitat retention efforts on riparian habitats, which span climatic gradients and are frequently used by black bears as movement corridors.

Spatial priorities for implementation

Spatial priorities for implementation of the adaptation actions described above include:

- Existing black bear core habitat areas and corridors (Appendix G.1), which will be important for maintaining black bear populations under current climate, and facilitating black bear response to future change (regardless of whether future declines in climatic suitability occur within the current corridor network).
- Climate-gradient corridors (Appendix G.1), which may help black bears disperse into cooler habitats as climate warms.
- The Okanagan Valley and other lower elevation areas in the greater Okanagan region. These areas already present barriers to black bear movement (Appendix G.1), and are expected to become less climatically suitable for the black bear as climate warms (Appendix G.3).

Maintaining and restoring connectivity across these valleys will be important for maintaining connectivity among higher elevation black bear habitats, and allowing black bears to disperse into newly climatically suitable areas.

- Highways, especially those that run along low-elevation valleys (e.g., Highway 97 and Highway 3A) and those that cross the Cascade Range (e.g., Highway 3).
- Riparian areas, which currently act as black bear movement corridors through dry, low elevation valleys, and also span climatic gradients, facilitating dispersal into cooler habitats.

Policy considerations

Referrals response

Actions for addressing climate impacts on black bear connectivity through First Nations and tribal referrals response processes include:

- For highway expansion projects, encouraging the use of highway design techniques that preserve connectivity (e.g., overpasses, open span bridges, and culverts), both on and off First Nation and tribal lands.
- Encouraging the incorporation of wildlife-friendly fencing into permitting and planning processes. Promoting the use of such designs may help facilitate black bear movement.

Land and water use planning and management

Actions for addressing climate impacts on black bear connectivity though land and water use planning and zoning include:

- Striving for community designs that limit fragmentation of habitat and include habitat corridors. In addition, directing development away from areas with high bear use may reduce incidents of human-bear interactions.
- Using large parcel zoning to maintain contiguity of natural areas within First Nations and tribal lands. Outside of these lands, work with private landowners and with environmental policy to maintain contiguous swaths of suitable land that will facilitate connectivity.
- Securing water rights to maintain moisture in riparian areas and wetlands that provide movement corridors and refugia through otherwise unsuitable shrub-steppe habitat in low elevation valleys.
- Investigating whether multiple priority species being affected in the same area can lead to greater pressure to change management practices if cumulative impacts can be demonstrated.
- Reviewing and implementing existing guidance and plans relating to black bear habitat management. Evaluate existing recommendations for opportunities to address climate impacts.
- Coordinating stewardship and management activities with provincial and local governments, NGOs, tribes and First Nations, and especially with landowners.

Transportation Planning

Actions for addressing climate impacts on black bear connectivity though transportation planning include:

- Coordinating with transportation agencies to evaluate appropriate management responses to potential changes in seasonal road openings and closings within black bear core habitat areas as snow conditions change, and higher elevation habitat potentially becomes more accessible to people.

- Coordinating with transportation agencies to ensure that new roads do not negatively impact climate-gradient corridors, or climate-resilient black bear core habitat and corridors (see Additional Research, below). When new roads are inevitable, mitigate barrier effects by incorporating crossing structures into road design.

Hunting regulations

Actions for addressing climate impacts on black bear connectivity through hunting regulations include:

- Considering timing hunting seasons on tribal and First Nation lands around dispersal and/or lowering take limits to reduce pressure on black bear populations.
- Considering issuing fines to individuals who kill black bears on First Nation lands.

Research needs

Future research that could help inform black bear connectivity conservation under climate change includes:

- Developing transboundary fire models. These models could improve assessment of potential impacts, and direct fire management activities toward core habitat areas and corridors identified as being at high fire risk.
- Developing transboundary pest models (e.g., mountain pine beetle, spruce budworm, and western pine beetle). These models could improve assessment of potential impacts, and direct forest health activities toward core habitat areas and corridors identified as being at high risk of insect or pathogen outbreaks.
- Developing fine-scaled, transboundary riparian models. These could help identify high quality riparian corridors that could facilitate movement despite general regional warming.
- Gathering additional empirical data on transboundary black bear movement to validate and improve existing corridor models.
- Identifying potential climate impacts on specific core habitat areas and corridors. Overlay projected changes in climate with existing black bear corridor networks to quantify expected impacts on specific areas within the network. This may help direct adaptation actions to appropriate areas.
- Identifying climate resilient black bear core habitat areas and corridors. Overlay corridor networks (Appendix G.1) with climatic niche models (Appendix G.3) and projected changes in vegetation (Appendix G.4), mountain pine beetle survival (Appendix G.5), and climate variables (Appendix G.6); core areas and corridors within the current range that are projected by multiple models to retain suitable climatic conditions and vegetation, have low risk of future mountain pine beetle survival, and to see the least change in relevant climatic variables, may be most likely to be resilient. Climate-resilient core habitat areas and corridors may be used to identify priority areas for the adaptation actions described above.
- Identifying corridors between locations with projected declines in climatic suitability and areas with projected stable or improving climatic suitability. Use climatic niche models (Appendix G.3) and vegetation projections (Appendix G.4) to identify potentially stable or improving locations. Use corridor models (Appendix G.1) to identify potential corridors for connecting vulnerable

black bear core habitat areas to areas projected to remain climatically suitable or become newly suitable.

References

1. Krosby, M., Michalak, J., Morgan, H., Robbins, T.O., Norheim, R., Mauger, G., and T. Murdock. 2016. The Washington-British Columbia Transboundary Climate-Connectivity Project: Identifying climate impacts and adaptation actions for wildlife habitat connectivity in the transboundary region of Washington and British Columbia. Climate Impacts Group, University of Washington.
2. Washington Wildlife Habitat Connectivity Working Group. 2010. Washington Connected Landscapes Project: Statewide Analysis. Washington Departments of Fish and Wildlife, and Transportation, Olympia, WA. www.waconnected.org.
3. Krosby, M., Tewksbury, J. J., Haddad, N., and J. Hoekstra. 2010. Ecological connectivity for a changing climate. *Conservation Biology* 24:1686-1689.
4. Cross, M. S., Hilty, J. A., Tabor, G. M., Lawler, J. J., Graumlich, L. J., and J. Berger. 2012. From connect-the-dots to dynamic networks: Maintaining and restoring connectivity as a strategy to address climate change impacts on wildlife. *In*: J. Brodie, E. Post, D. Doak, eds. *Conserving wildlife populations in a changing climate*. Chicago University Press.
5. Heller, N. E., and E. S. Zavaleta. 2009. Biodiversity management in the face of climate change: a review of 22 years of recommendations. *Biological Conservation* 142**:**14–32.
6. Cross, M.S., et al. 2012. The Adaptation for Conservation Targets (ACT) framework: a tool for incorporating climate change into natural resource management. *Environmental Management* 50:341–351.
7. Washington Wildlife Habitat Connectivity Working Group. 2011. Washington Connected Landscapes Project: Climate gradient corridors report. Washington Departments of Fish and Wildlife, and Transportation. Olympia, WA. www.waconnected.org.
8. Integrated Scenarios of the Future Northwest Environment. http://climate.nkn.uidaho.edu/IntegratedScenarios
9. Pacific Climate Impacts Consortium (PCIC), Regional Analysis Tool. 2014. https://www.pacificclimate.org/analysis-tools/regional-analysis-tool
10. Pacific Northwest Climate Change Vulnerability Assessment (PNWCCVA). http://www.climatevulnerability.org/
11. McKenzie, D., Gedalof, Z., and D.L. Peterson, and P. Mote. 2004. Climatic change, wildfire, and conservation. *Conservation Biology* 18:890-902.
12. Beckmann, J.P., and J. Berger. 2003. Rapid ecological and behavioural changes in carnivores: the responses of black bears (*Ursus americanus*) to altered food. *Journal of Zoology* 261:207–212. doi:10.1017/S0952836903004126

Glossary of Terms

Assisted migration – Species and populations are deliberately planted or transported to new suitable habitat locations, typically in response to declines in historic habitat quality resulting from rapid environmental change, principally climate change.

Centrality — Refers to a group of landscape metrics that rank the importance of habitat patches or linkages in providing movement across an entire network, i.e., as "gatekeepers" of flow across a landscape.[v]

Connectivity — Most commonly defined as the degree to which the landscape facilitates or impedes movement among resource patches.[vi] Can be important for maintaining ecological, population-level, or evolutionary processes.

Core Areas — Large blocks (10,000+ acres) of contiguous lands with relatively high landscape permeability.

Corridor — Refers to modeled movement routes or physical linear features on the landscape (e.g., continuous strips of riparian vegetation or transportation routes). In this document, the term "corridor" is most often used in the context of modeled least-cost corridors, i.e., the most efficient movement pathways for wildlife and ecological processes that connect HCAs or core areas. These are areas predicted to be important for migration, dispersal, or gene flow, or for shifting ranges in response to climate change and other factors affecting the distribution of habitat.

Desiccation – Extreme water deprivation, or process of extreme drying.

Dispersal — Relatively permanent movement of an individual from an area, such as movement of a juvenile away from its place of birth.

Fracture Zone — An area of reduced permeability between core areas. Most fracture zones need significant restoration to function as reliable linkages. Portions of a fracture zone may be potential linkage zones.

Habitat Connectivity — See Connectivity.

Landscape Connectivity — See Connectivity.

Permeability — The ability of a landscape to support movement of plants, animals, or processes.

Pinch point — Portion of the landscape where movement is funneled through a narrow area. Pinch points can make linkages vulnerable to further habitat loss because the loss of a small area can sever the linkage entirely. Synonyms are bottleneck and choke point.

---

[v] Carroll, C. 2010. Connectivity analysis toolkit user manual. Version 1.1. Klamath Center for Conservation Research, Orleans, California. Available at www.connectivitytools.org (accessed January 2016).

[vi] Taylor, P. D., L. Fahrig, K. Henein, and G. Merriam. 1993. Connectivity is a vital element of landscape structure. *Oikos* 68: 571-573.

Refugia – Geographical areas where a population can survive through periods of unfavorable environmental conditions (e.g., climate-related effects).

Thermal barriers – Water temperatures warm enough to prevent migration of a given fish species. These barriers can prevent or delay spawning for migrating salmonids.

Appendices G.1-6

Appendices include all materials used to identify potential climate impacts on habitat connectivity for case study species, vegetation systems, and regions. For black bear, these materials include:

Appendix G.1. Habitat connectivity models
Appendix G.2. Conceptual model of habitat connectivity
Appendix G.3. Climatic niche models
Appendix G.4. Projected changes in vegetation communities
Appendix G.5. Projected changes in probability of mountain pine beetle survival
Appendix G.6. Projected changes in relevant climatic variables

All maps included in these appendices are derived from a few primary datasets, chosen because they are freely available, span all or part of the transboundary region, and reflect the expertise of project science partners. These sources include habitat connectivity models produced by the Washington Connected Landscapes Project,[2,7] future climate projections from the Integrated Scenarios of the Pacific Northwest Environment[8] and the Pacific Climate Impacts Consortium's Regional Analysis Tool,[9] and models of projected range shifts and vegetation change produced as part of the Pacific Northwest Climate Change Vulnerability Assessment.[10]

All maps are provided at three geographic extents corresponding to the distinct geographies of the three project partnerships (Fig. G.2):

i. **Okanagan Nation Territory**, the assessment area for project partners: Okanagan Nation Alliance and its member bands and tribes, including Colville Confederated Tribes.

ii. **The Okanagan-Kettle Region**, the assessment area for project partners: Transboundary Connectivity Working Group (i.e., the Washington Habitat Connectivity Working Group and its BC partners).

iii. **The Washington-British Columbia Transboundary Region**, the assessment area for project partners: BC Parks; BC Forests, Lands, and Natural Resource Operations; US Forest Service; and US National Park Service.

All project reports, data layers, and associated metadata are freely available online at:
https://nplcc.databasin.org/galleries/5a3a424b36ba4b63b10b8170ea0c915e

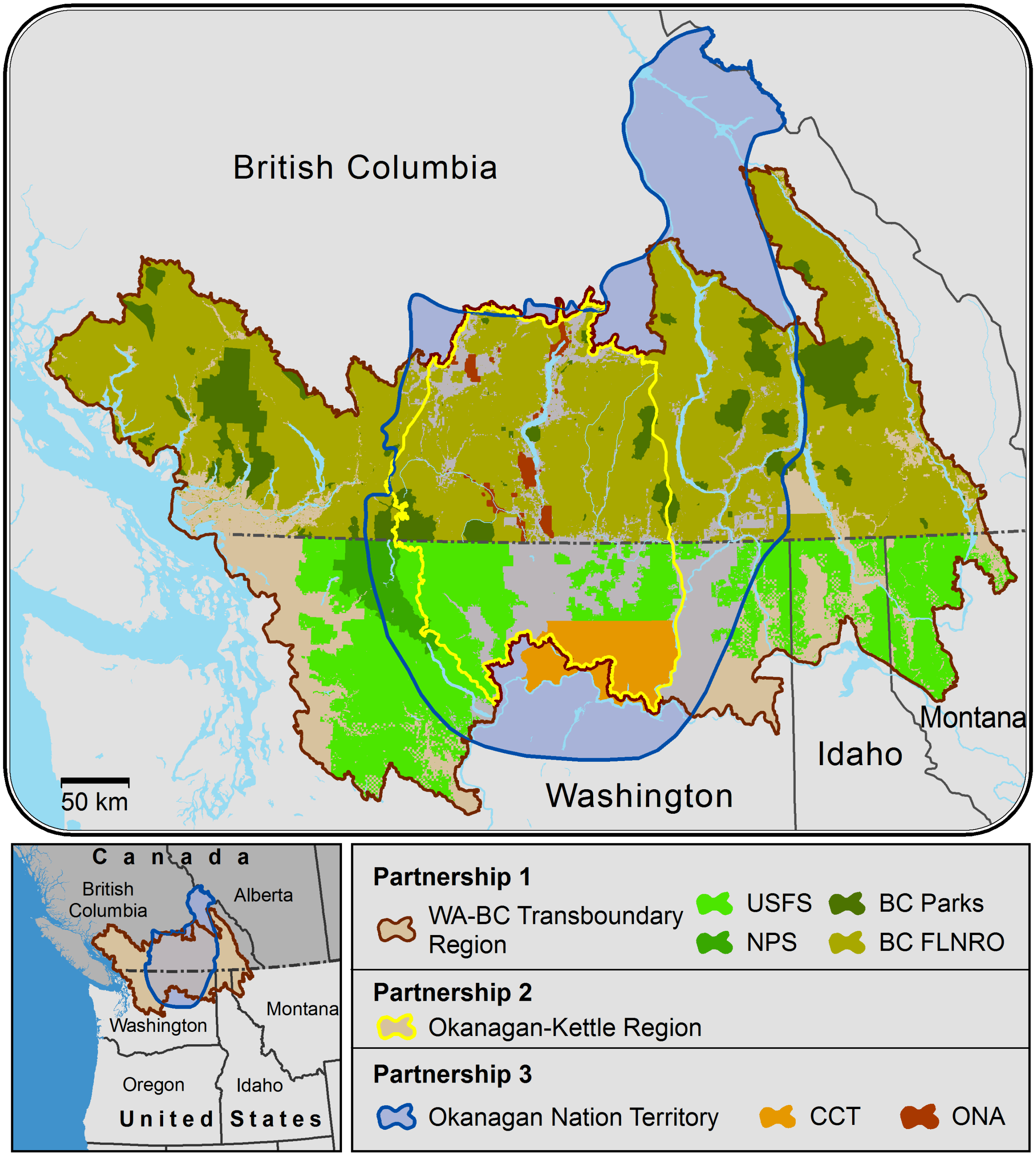


Figure G.2. Project partners and assessment areas.

Appendix G.1. Habitat Connectivity Models

Habitat connectivity models are available from the Washington Connected Landscapes Project.[vii] These models can be used to prioritize areas for maintaining and restoring habitat connectivity now and in the future as the climate changes. Available models include species corridor networks, landscape integrity corridor networks, and climate-gradient corridor networks. These models are available at two distinct scales (though for many species, only one scale is available or was selected for use by project participants): 1) **WHCWG Statewide** models span Washington State and surrounding areas of Oregon, Idaho, and British Columbia; 2) **WHCWG Columbia Plateau** models span the Columbia Plateau ecoregion within Washington State, and do not extend into British Columbia.

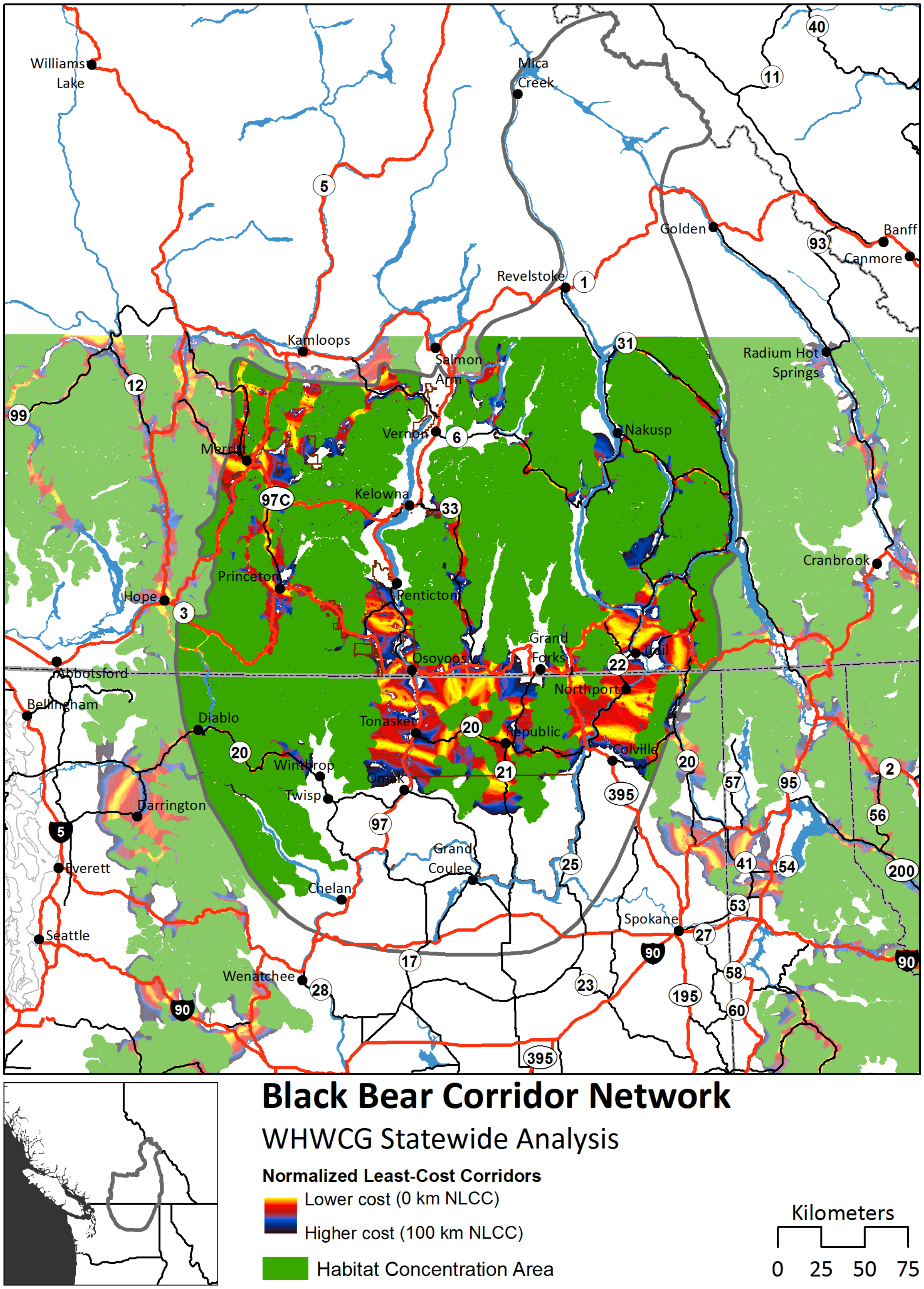
a) **WHCWG Statewide Analysis: Black Bear Corridor Network.**[2] This map shows Habitat Concentration Areas (HCAs, green polygons), which are large, contiguous areas featuring little resistance to species movement; and corridors (glowing yellow areas) connecting HCAs, modeled using least cost corridor analysis. The northern extent of this analysis falls just north of Kamloops, BC.

b) **WHCWG Statewide Analysis: Climate-Gradient Corridor Network (Temperature + Landscape Integrity).**[7] This map shows corridors (glowing white areas, with resistance to movement increasing as white fades to black) connecting core habitat areas (polygons, shaded to reflect mean annual temperatures) that are of high landscape integrity (i.e., have low levels of human modification) and differ in temperature by >1 ^{o}C. These corridors thus allow for movement between relatively warmer and cooler core habitat areas, while avoiding areas of low landscape integrity (e.g., roads, agricultural areas, urban areas), and minimizing major changes in temperature along the way (e.g., crossing over cold peaks or dipping into warm valleys). The northern extent of this analysis falls just north of Kamloops, BC.

[vii] For detailed methodology and data layers see http://www.waconnected.org.

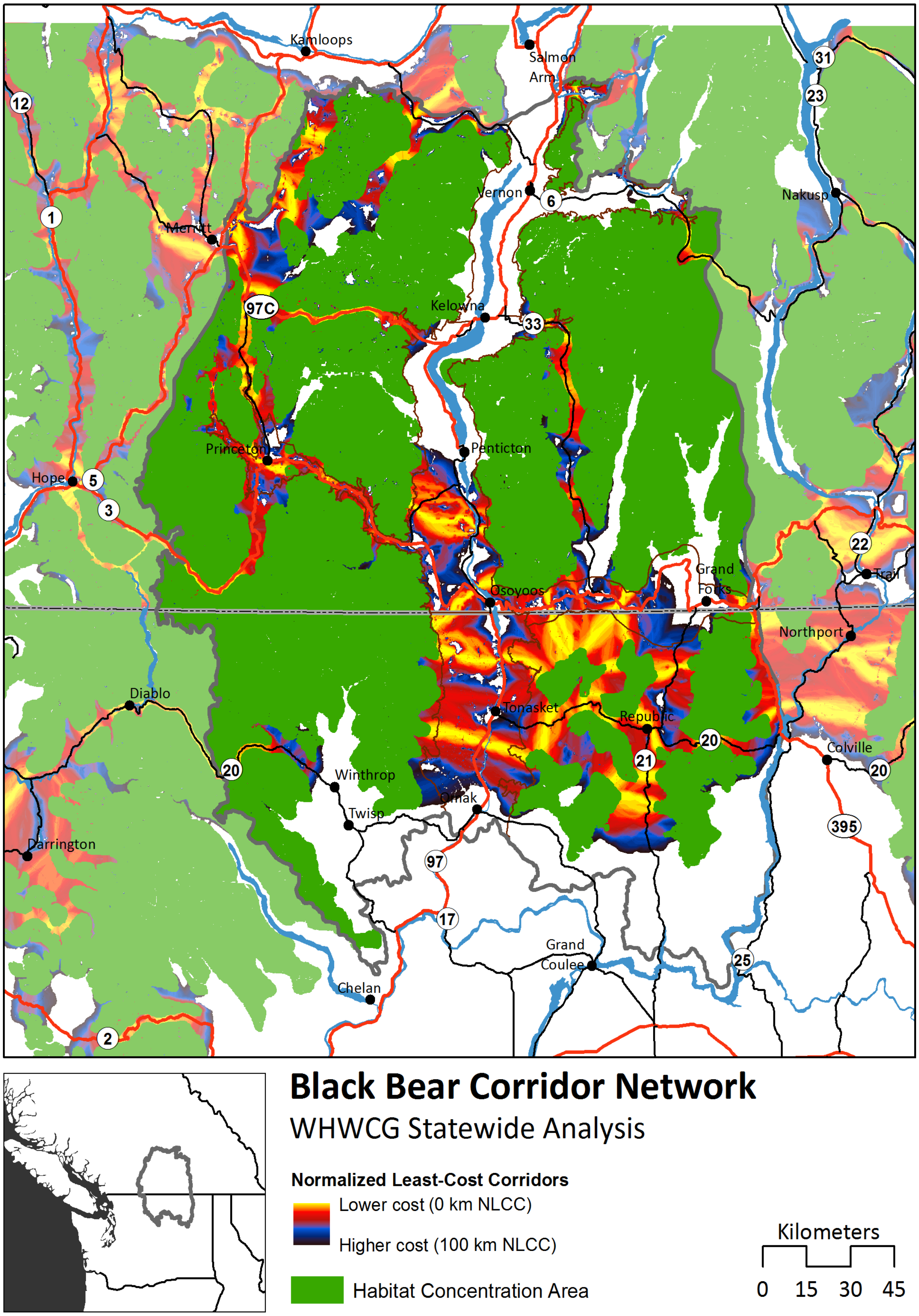
Appendix G.1a. WHCWG Statewide Analysis: Black Bear Corridor Network

i) Extent: Okanagan Nation Territory



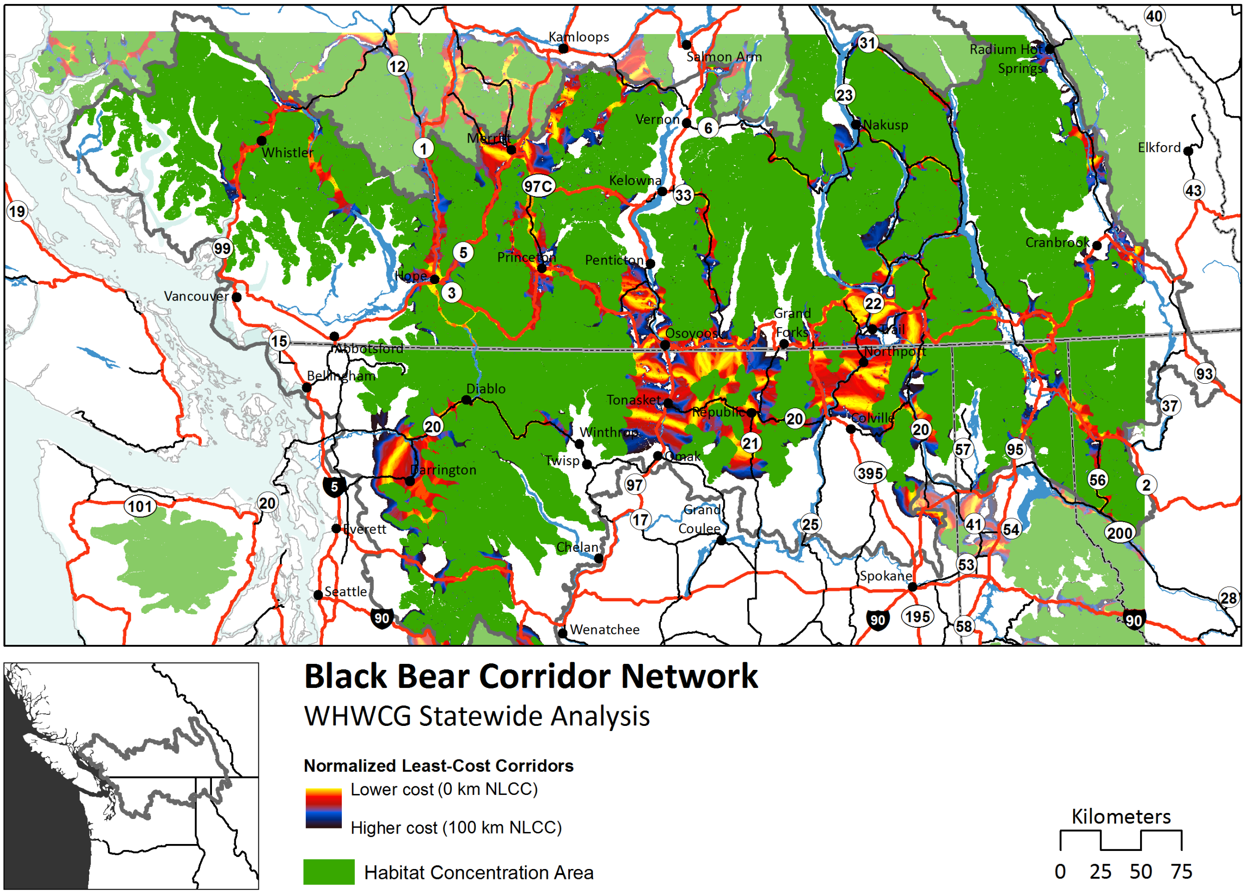
Appendix G.1a. WHCWG Statewide Analysis: Black Bear Corridor Network

ii) Extent: Okanagan-Kettle Region



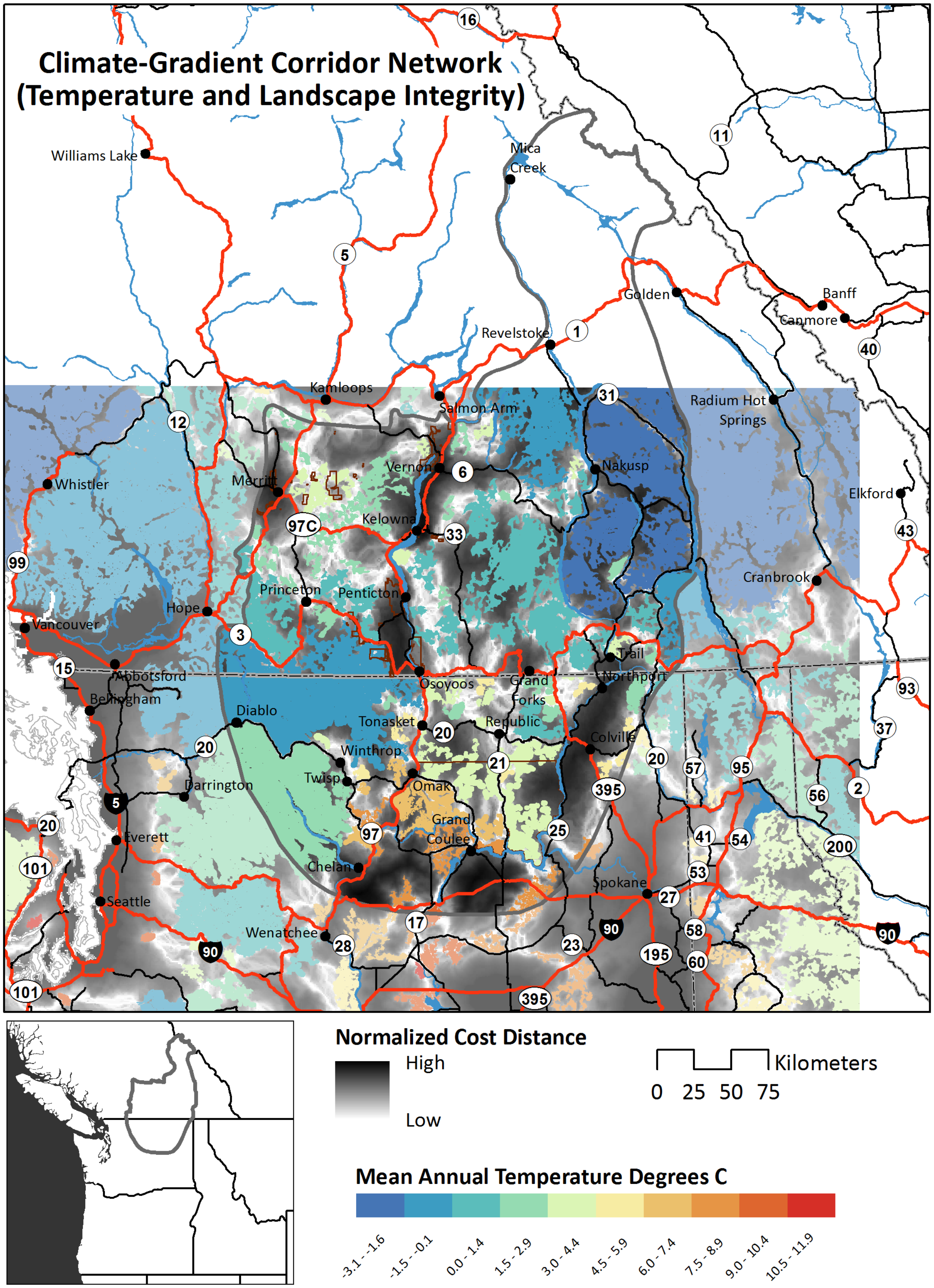
Appendix G.1a. WHCWG Statewide Analysis: Black Bear Corridor Network

iii) Extent: Washington-British Columbia Transboundary Region



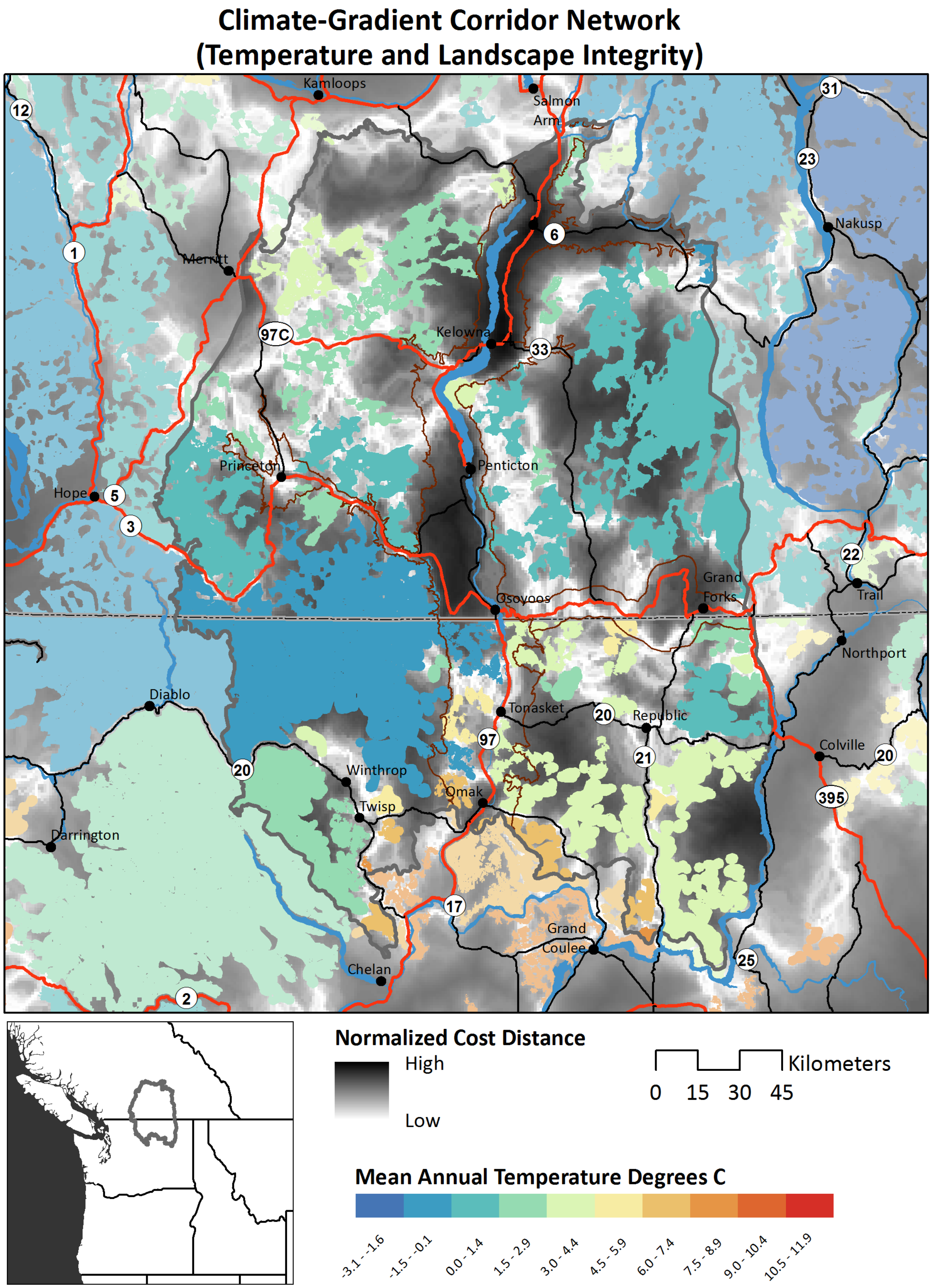
Appendix G.1b. WHCWG Statewide Analysis: Climate-Gradient Corridor Network (Temperature + Landscape Integrity)

i) Extent: Okanagan Nation Territory



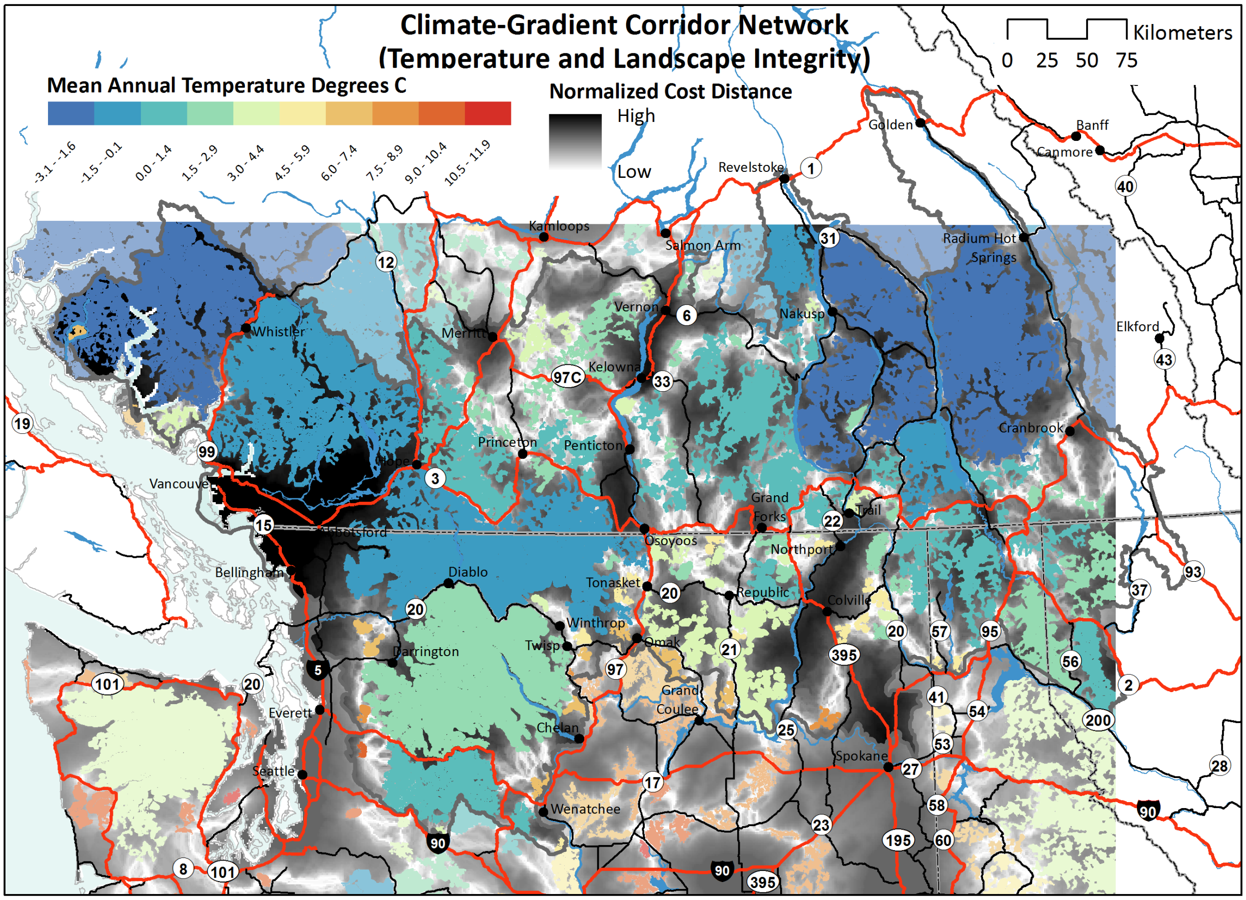
Appendix G.1b. WHCWG Statewide Analysis: Climate-Gradient Corridor Network (Temperature + Landscape Integrity)

ii) Extent: Okanagan-Kettle Region



Appendix G.1b. WHCWG Statewide Analysis: Climate-Gradient Corridor Network (Temperature + Landscape Integrity)

iii) Extent: Washington-British Columbia Transboundary Region



Appendix G.2. Conceptual Model of Habitat Connectivity

To identify potential climate impacts on transboundary black bear habitat connectivity, project partners created a conceptual model that identifies the key landscape features and processes expected to influence black bear habitat connectivity, which of those are expected to be influenced by climate, and how. Simplifying complex ecological systems in such a way can make it easier to identify specific climate impacts and adaptation actions. For this reason, conceptual models have been promoted as useful adaptation tools, and have been applied in a variety of other systems.[6] The black bear conceptual model was developed using peer-reviewed articles and reports, project participant expertise, and review by species experts. That said, the resulting model is intentionally simplified, and should not be interpreted to represent a comprehensive assessment of the full suite of landscape features and processes contributing to black bear habitat connectivity.

Conceptual models illustrate the relationships between the key landscape features (white boxes), ecological processes (rounded corner purple boxes), and human activities (rounded corner blue boxes) that influence the quality and permeability of core habitat and dispersal habitat for a given species. Climatic variables for which data on projected changes are available are highlighted with a yellow outline. Green arrows indicate a positive correlation between linked variables (i.e., as variable x increases variable y increases); note that a positive correlation is not necessarily beneficial to the species. Red arrows indicate a negative relationship between variables (i.e., as variable x increases, variable y decreases); again, negative correlations are not necessarily harmful to the species.

Expert reviewers for the black bear conceptual model included:

- Alison Peatt, RPBio, Environmental planner for South Okanagan-Similkameen communities
- Okanagan Nation Alliance (consulting biologist)

Key references used to create the black bear conceptual model included:

Gaines, W.L., Lyons, A.L., Lehmkuhl, J.F., and K.J. Raedeke. 2005. Landscape evaluation of female black bear habitat effectiveness and capability in the North Cascades, Washington. *Biological Conservation* 125:411–425.

Lyons, A.L., Gaines, W.L., and C. Servheen. 2003. Black bear resource selection in the northeastern Cascades, Washington. *Biological Conservation* 113:55–62.

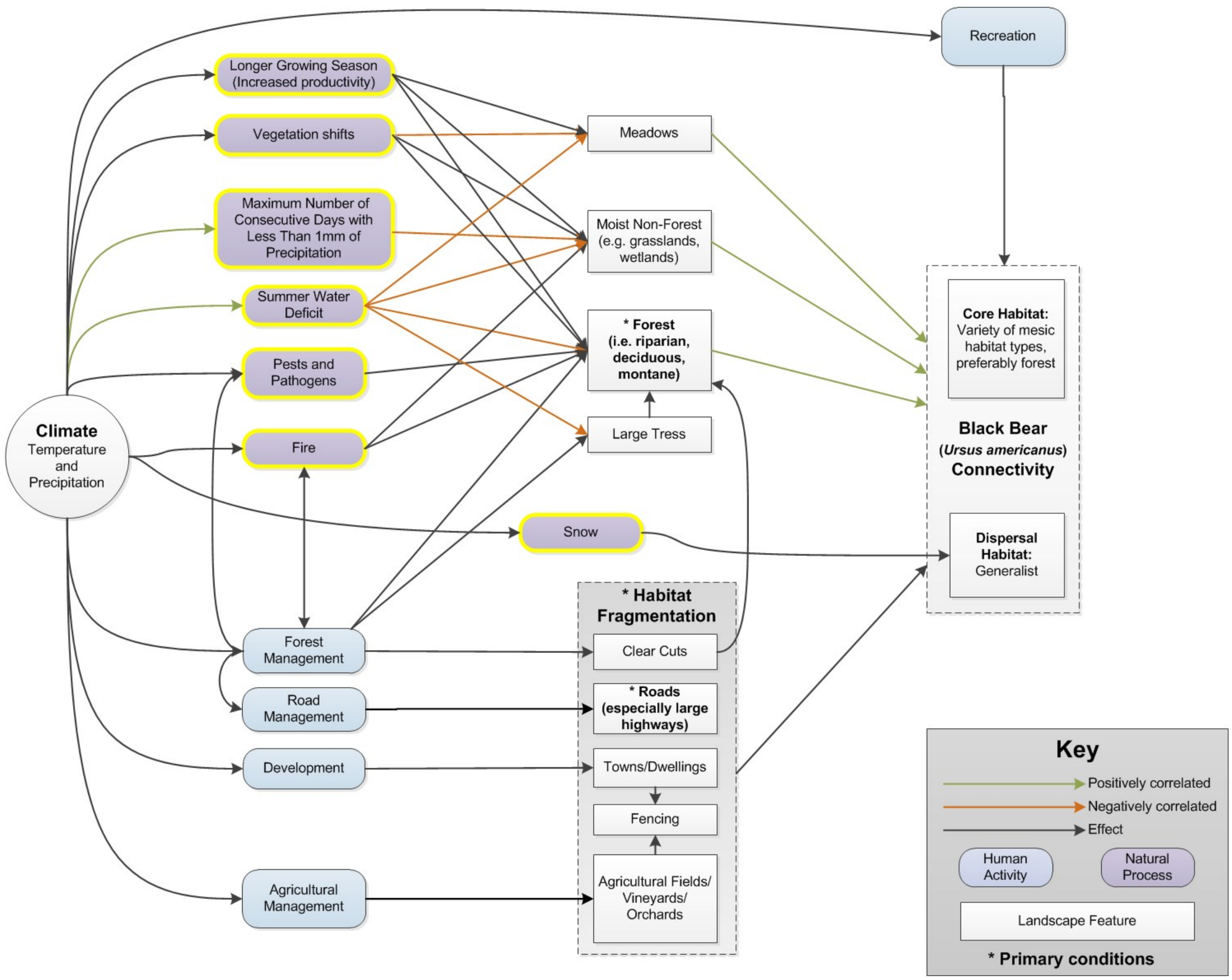
Singleton, P.H., Gaines, W.L., and J.F. Lehmkuhl. 2002. Landscape permeability for large carnivores in Washington: A geographic information system weighted-distance and least-cost corridor assessment. Research Paper N-549. U. S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Ulev, E. 2007. *Ursus americanus*. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available at: http://www.fs.fed.us/database/feis/ [2015, May 27].

Washington Wildlife Habitat Connectivity Working Group (WHCWG). 2010. Washington Connected Landscapes Project: Statewide Analysis. Washington Departments of Fish and Wildlife, and Transportation, Olympia, WA.

Wertz, T.L., Akenson, J.J., Henjum, M.G., and E.L. Bull. 2000. Home range and dispersal patterns of subadult black bears in northeastern Oregon. Western black bear Workshop 7:93–100.

Appendix G.2. Conceptual model of black bear habitat connectivity



Appendix G.3. Climatic Niche Models

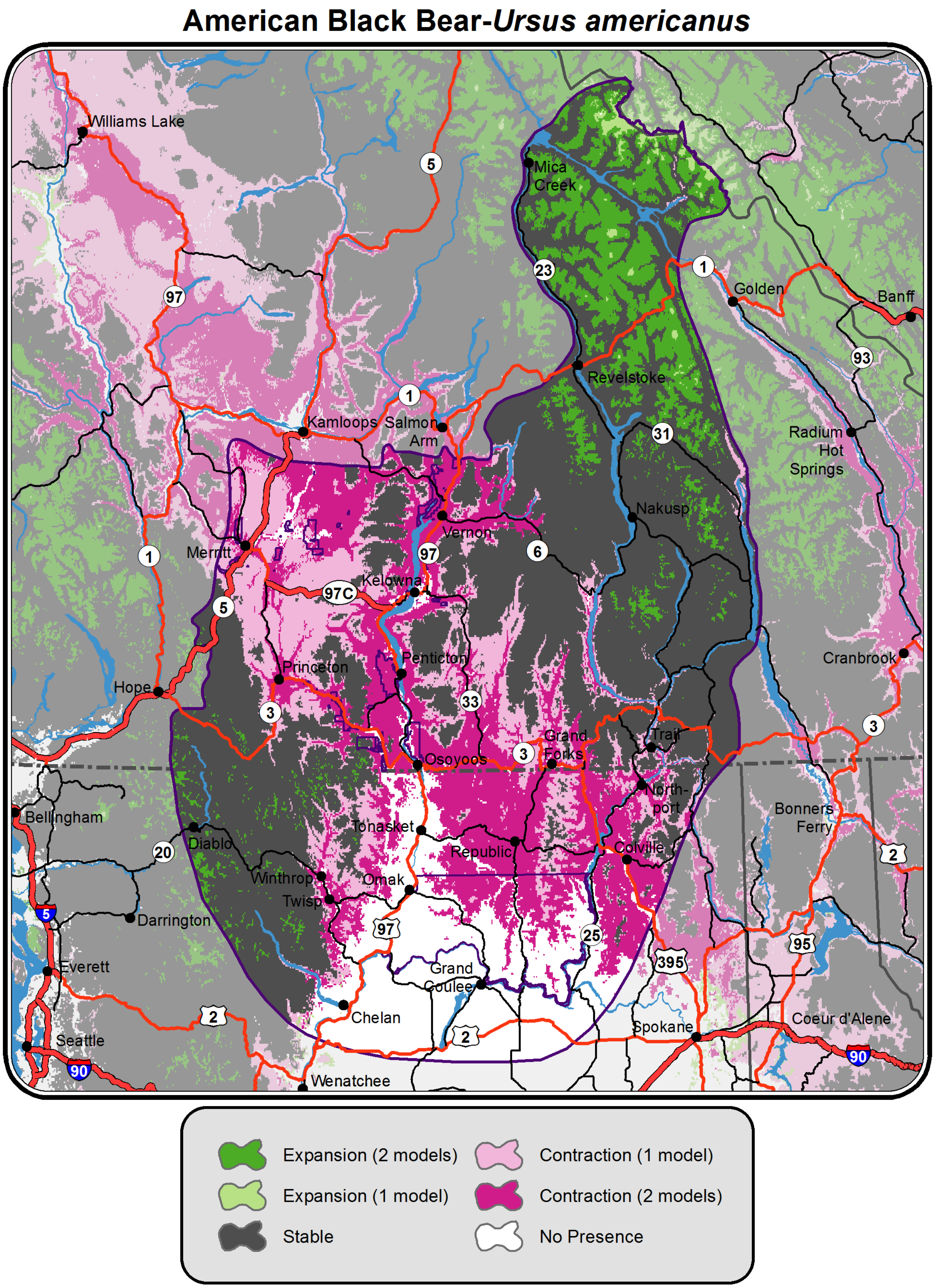
Climatic niche models (CNM) mathematically define the climatic conditions within each species' current geographic distribution, and then apply projected climate changes to identify where on the landscape those climate conditions are projected to be located in the future. These maps show CNM results based on results from two CMIP3 Global Circulation Models (GCMs): CGCM3.1(T47) and UKMO-HadCM3.[viii] Both models use the A2 (high) emissions scenario.[ix] CNMs are based on climate conditions alone and do not account for dispersal ability, genetic adaptation, interspecies interactions, or other aspects of habitat suitability. Once projected range shifts were modeled, current land uses and projected vegetation types (identified using Shafer et al. 2015[x]) that are unlikely to support species occurrence were removed. For example, areas currently defined as urban were removed for species unable to live in urban landscapes, and grassland habitats were removed for forest-dependent species. Both would be shown as unsuitable.

Dark gray areas indicate areas of the species' current range that are projected to remain climatically suitable by both GCMs (i.e., range is expected to remain "stable"). Dark pink areas are projected to become less climatically suitable by both GCMs (i.e., range is expected to "contract"). Light pink areas are projected to become less suitable under one model but remain stable under the other. Dark green areas are areas that are not within the species' current range but are projected to become climatically suitable by both GCMs (i.e., the range is expected to "expand"). Light green areas are projected to become climatically suitable by one GCM, but not the other.

[viii] CGCM3.1(T47) and UKMO-HadCM3 are two Global Circulation Models (GCMs) which each project different potential future climate scenarios. The UKMO-HadCM3 model projects a much hotter and drier summer, while the CGCM3.1(T47) projects greater precipitation increases in spring, summer and fall. For these reasons, the UKMO-HadCM3 could be considered a "hot-dry" future, while the CGCM3.1(T47) could be considered a "warm-wet" future within the Pacific Northwest.
[ix] Emissions scenarios were developed by climate modeling centers for use in modeling global and regional climate-related effects. A2 is a high, "business as usual" scenario in which emissions of greenhouse gases continue to rise until the end of the 21st century, and atmospheric CO_2 concentrations more than triple by 2100 relative to pre-industrial levels.
[x] Shafer, S.L., Bartlein, P.J , Gray, E.M., and R.T. Pelltier. 2015. Projected future vegetation changes for the northwest United States and southwest Canada at a fine spatial resolution using a dynamic global vegetation model. *PLoS ONE* 10: e0138759. doi:10.1371/journal.pone.0138759

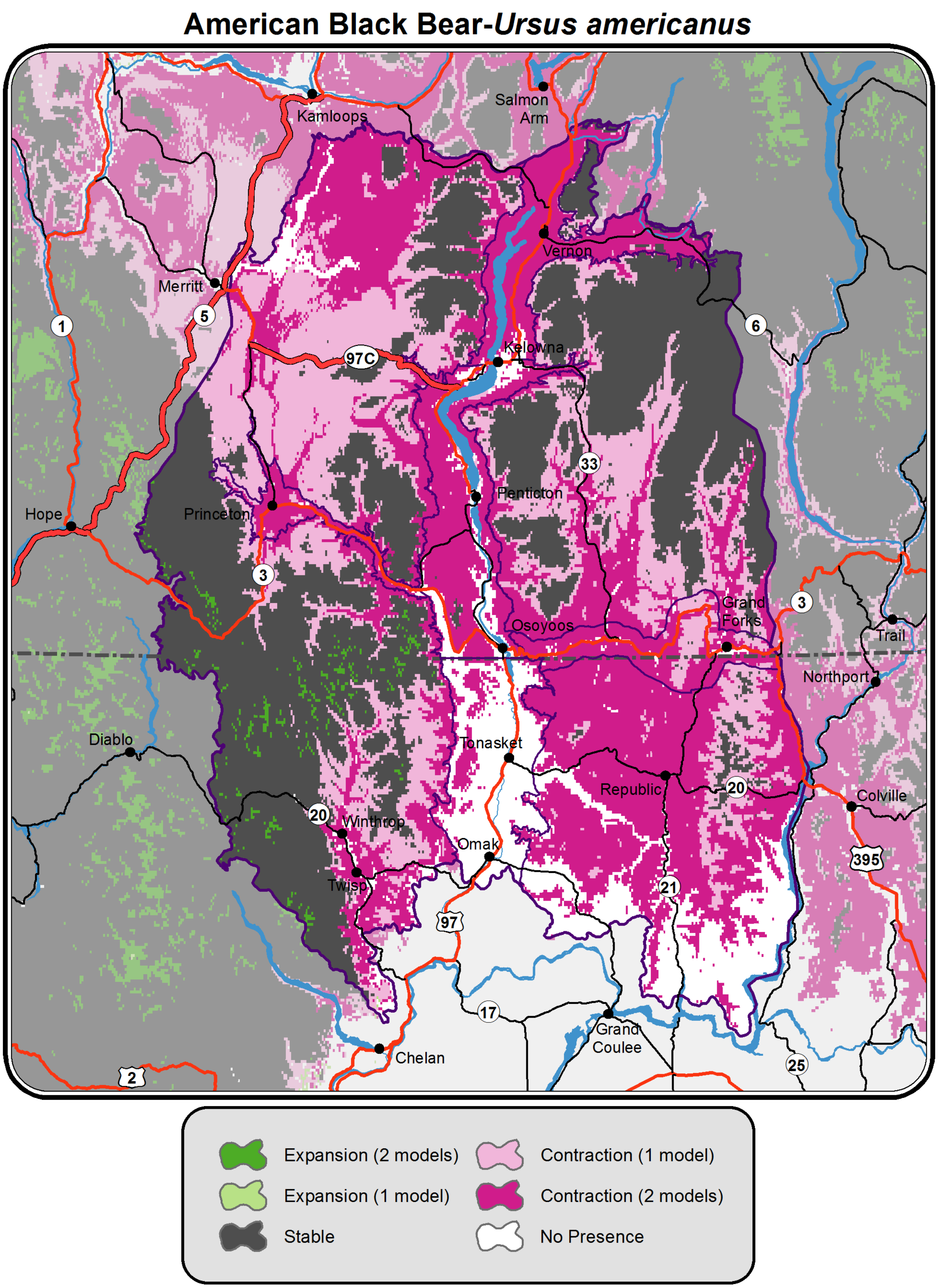
Appendix G.3. Black Bear Climatic Niche Model

i) Extent: Okanagan Nation Territory



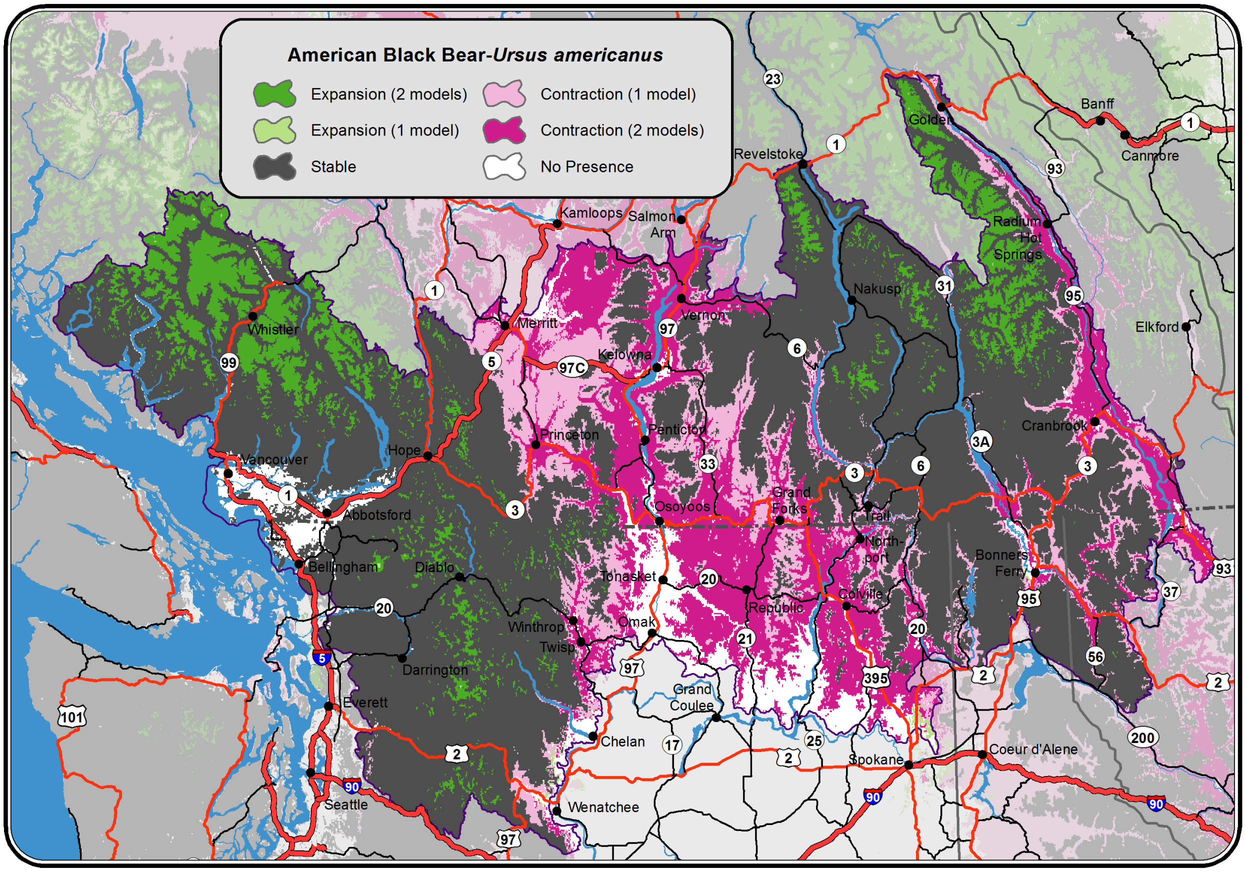
Appendix G.3. Black Bear Climatic Niche Model

ii) Extent: Okanagan-Kettle Region



Appendix G.3. Black Bear Climatic Niche Model

iii) Extent: Washington-British Columbia Transboundary Region



Appendix G.4. Projected Changes in Vegetation

Two types of models are available that project future changes in vegetation that could affect a species' habitat connectivity: climatic niche models and mechanistic models. Climatic niche vegetation models mathematically define the climatic conditions within a given vegetation type's current distribution and then project where on the landscape those conditions are expected to occur in the future. These models do not incorporate other important factors that determine vegetation such as soil suitability, dispersal, competition, and fire. In contrast, mechanistic vegetation models do incorporate these ecological processes, as well as projected climate changes and the potential effects of carbon dioxide fertilization. However, mechanistic models only project changes to very general vegetation types (e.g., cold forest, shrub steppe, or grassland). Both types of models included below show vegetation model results based on results from two CMIP3 Global Circulation Models (GCMs): CGCM3.1(T47) and UKMO-HadCM3.[xi] Both models also use the A2 (high) emissions scenario.[xii]

a) **Biome Climatic Niche Vegetation Model.** [xiii] This climatic niche vegetation model shows the projected response of biomes or forest types to projected climate change.

b) **Mechanistic Vegetation Model.**[xiv] This mechanistic vegetation model shows simulated vegetation composition and distribution patterns under climate change.

[xi] CGCM3.1(T47) and UKMO-HadCM3 are two Global Circulation Models (GCMs) which each project different potential future climate scenarios. The UKMO-HadCM3 model projects a much hotter and drier summer, while the CGCM3.1(T47) projects greater precipitation increases in spring, summer and fall. For these reasons, the UKMO-HadCM3 could be considered a "hot-dry" future, while the CGCM3.1(T47) could be considered a "warm-wet" future within the Pacific Northwest.

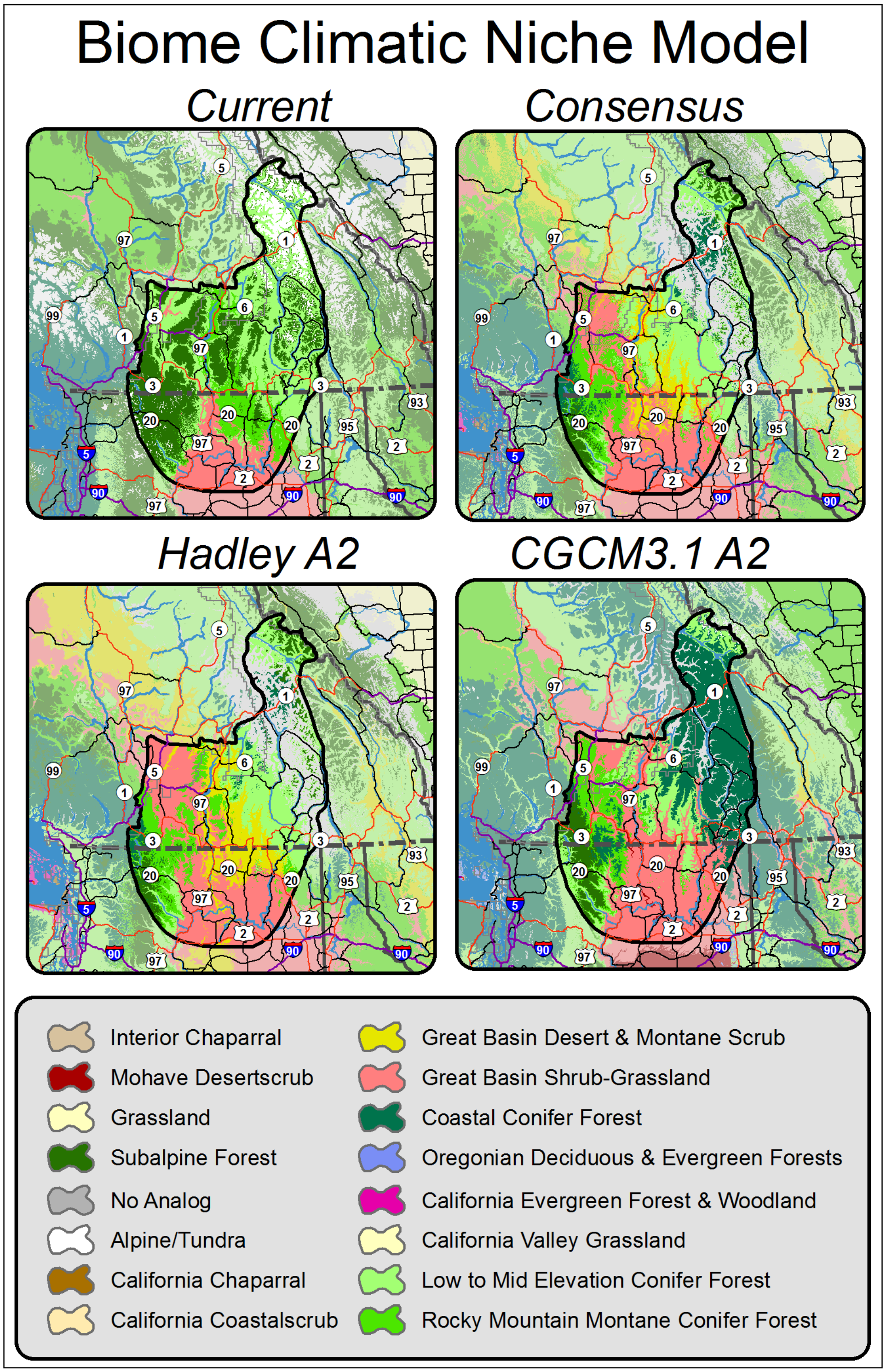
[xii] Emissions scenarios were developed by climate modeling centers for use in modeling global and regional climate-related effects. A2 is a high, "business as usual" scenario in which emissions of greenhouse gases continue to rise until the end of the 21st century, and atmospheric CO_2 concentrations more than triple by 2100 relative to pre-industrial levels.

[xiii] Rehfeldt, G.E., Crookston, N.L., Sánez-Romero, C., Campbell, E.M. 2012. North American vegetation model for land-use planning in a changing climate: a solution to large classification problems. *Ecological Applications* 22: 119-141.

[xiv] Shafer, S.L., Bartlein, P.J , Gray, E.M., and R.T. Pelltier. 2015. Projected future vegetation changes for the Northwest United States and Southwest Canada at a fine spatial resolution using a dynamic global vegetation model. *PLoS ONE* 10: e0138759. doi:10.1371/journal.pone.0138759.

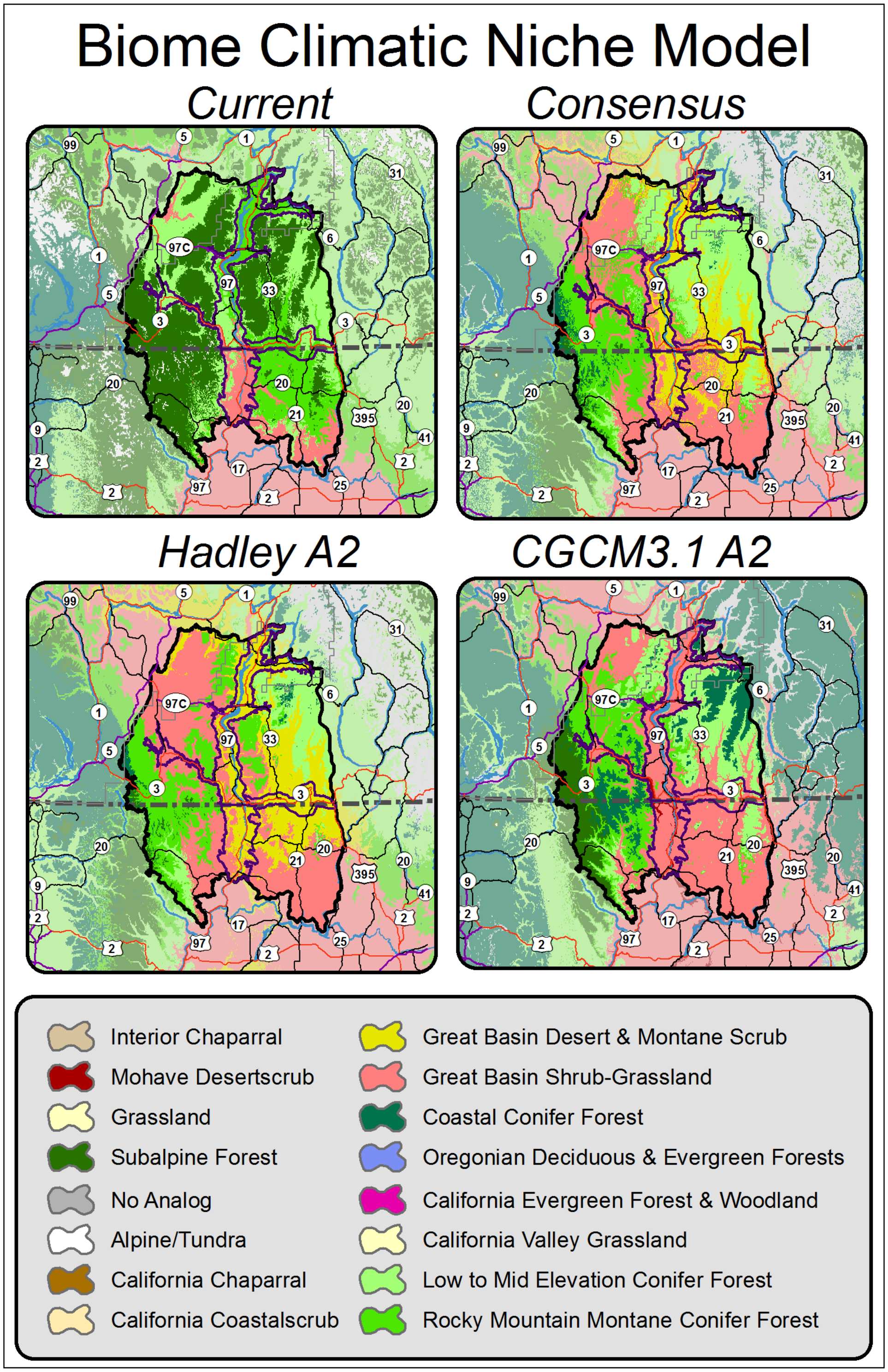
Appendix G.4a. Biome Climatic Niche Model

i) Extent: Okanagan Nation Territory



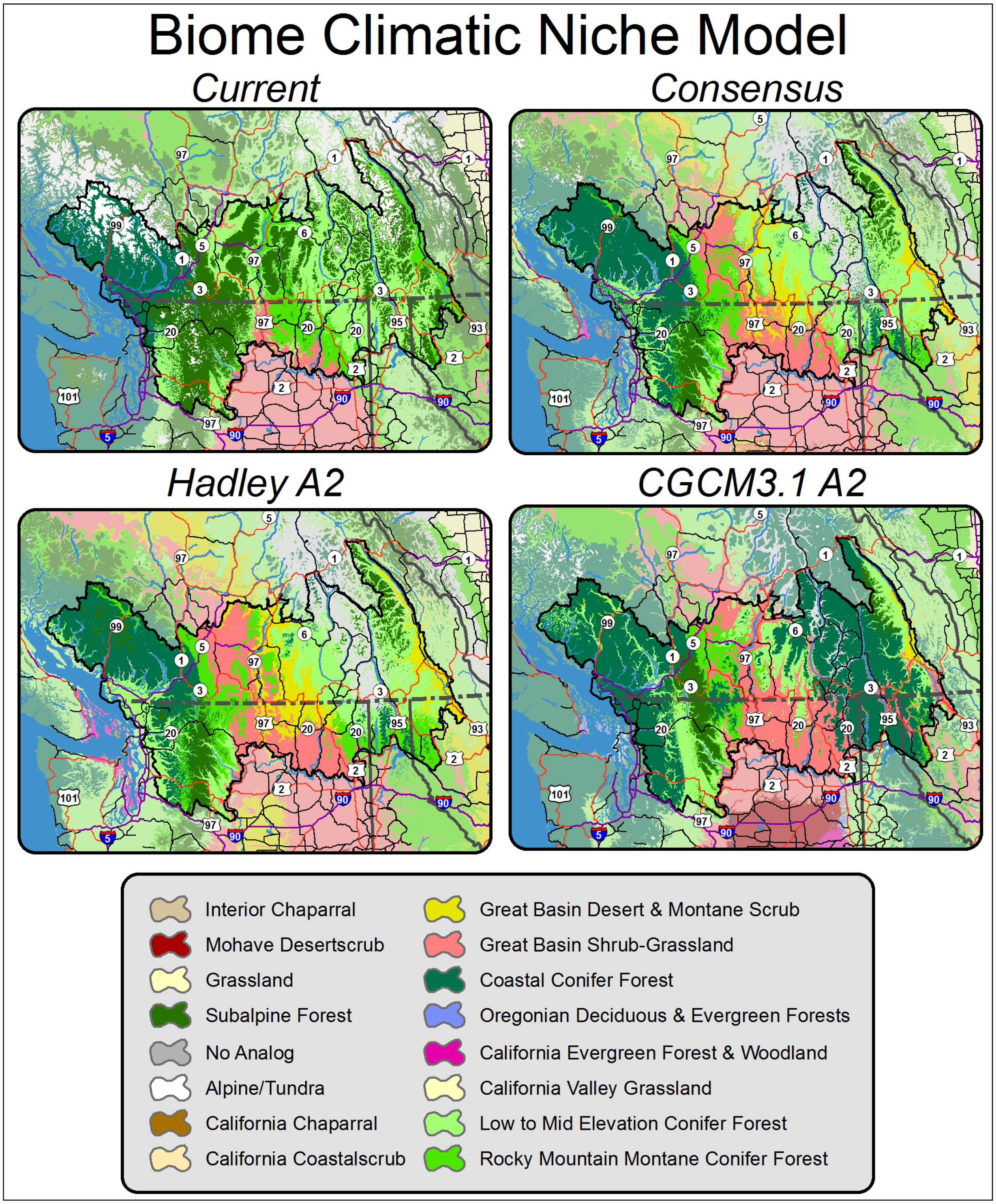
Appendix G.4a. Biome Climatic Niche Model

ii) Extent: Okanagan-Kettle Region



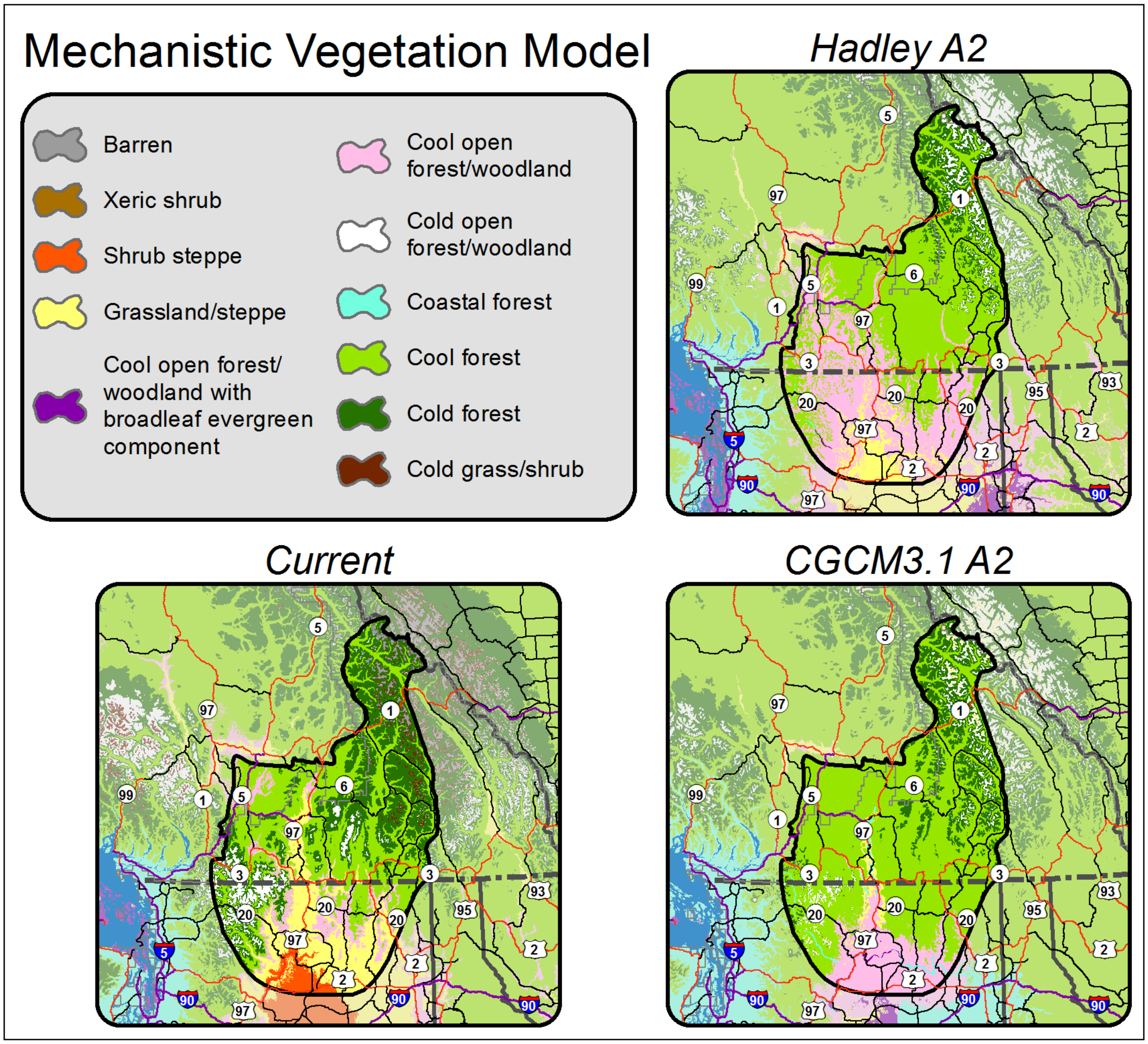
Appendix G.4a. Biome Climatic Niche Model

iii) Extent: Washington-British Columbia Transboundary Region



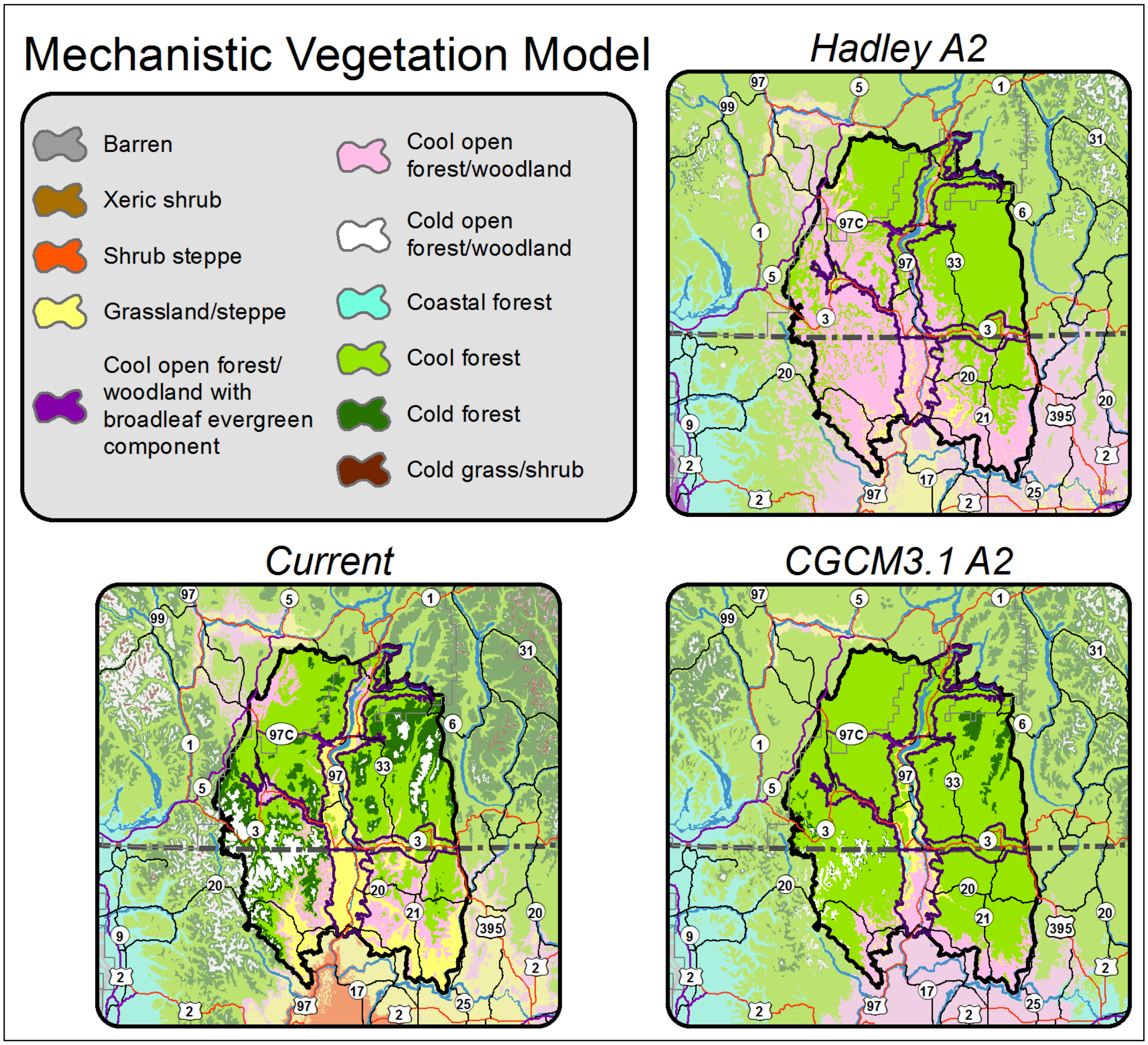
Appendix G.4b. Mechanistic Vegetation Model

i) Extent: Okanagan Nation Territory



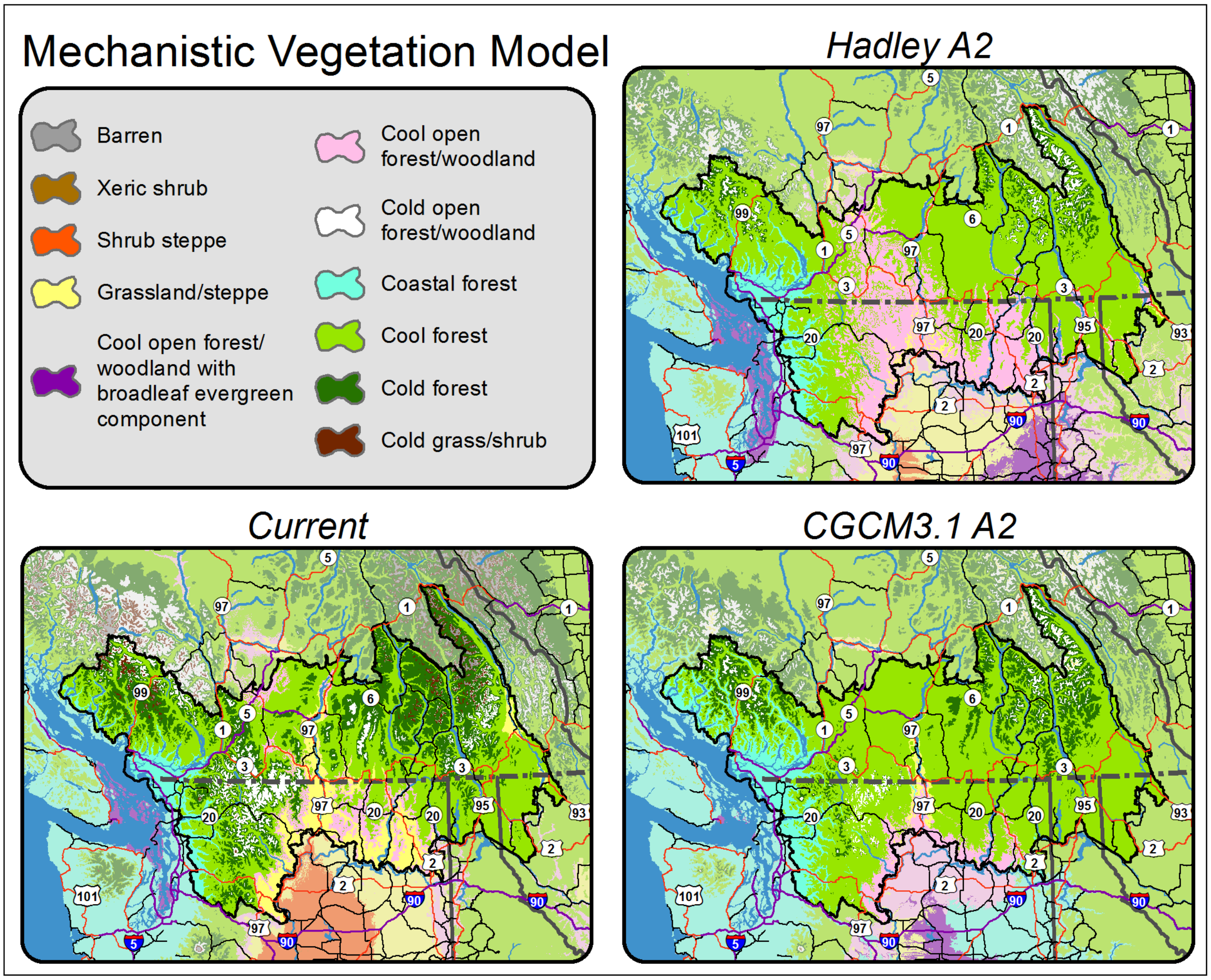
Appendix G.4b. Mechanistic Vegetation Model

ii) Extent: Okanagan-Kettle Region



Appendix G.4b. Mechanistic Vegetation Model

iii) Extent: Washington-British Columbia Transboundary Region



Appendix G.5. Projected Changes in Probability of Mountain Pine Beetle Survival

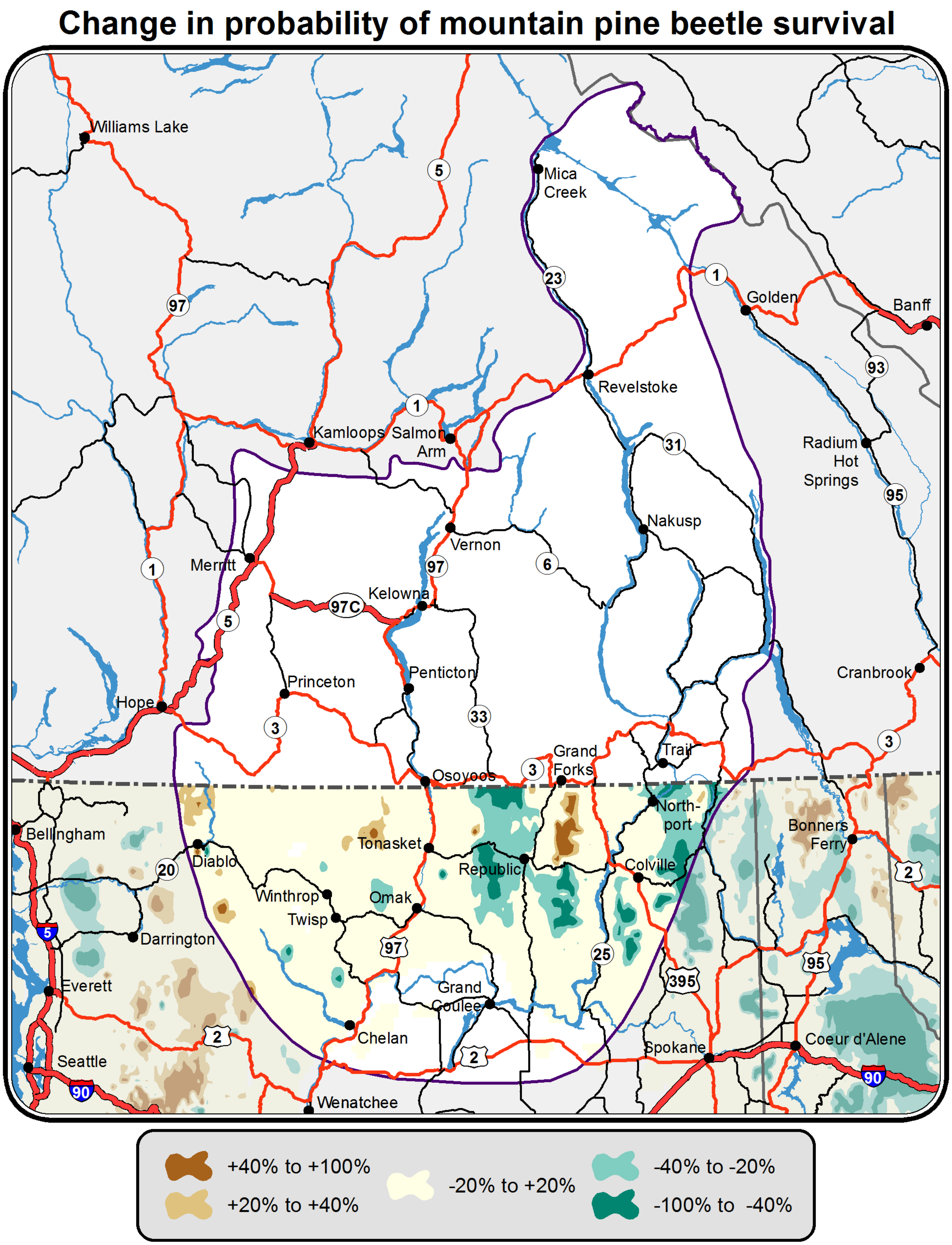
Projected changes in the probability of climatic suitability for mountain pine beetles for the period 2001 to 2030 (relative to 1961 to 1990), where brown indicates areas where pine beetles are projected to increase in the future and green indicates areas where pine beetles are projected to decrease in the future.[xv,xvi]

[xv] Mote, P.W., Snover, A.K., Capalbo, S.M., Eigenbrode, S., Glick, P., Littell, J.S., Raymondi, R., Reeder, S. 2014. Chapter 21 in *Climate Change Impacts in the United States: The Third U.S. National Climate Assessment*, J. Melillo, Terese (T.C.) Richmond, and G.W. Yohe, Eds., U.S. Global Change Research Program, 16-1-nn.

[xvi] Changes in probability of survival are based on climate-dependent factors important in beetle population success, including cold tolerance, spring precipitation, and seasonal heat accumulation. [xv] Projections are only available for the United States.

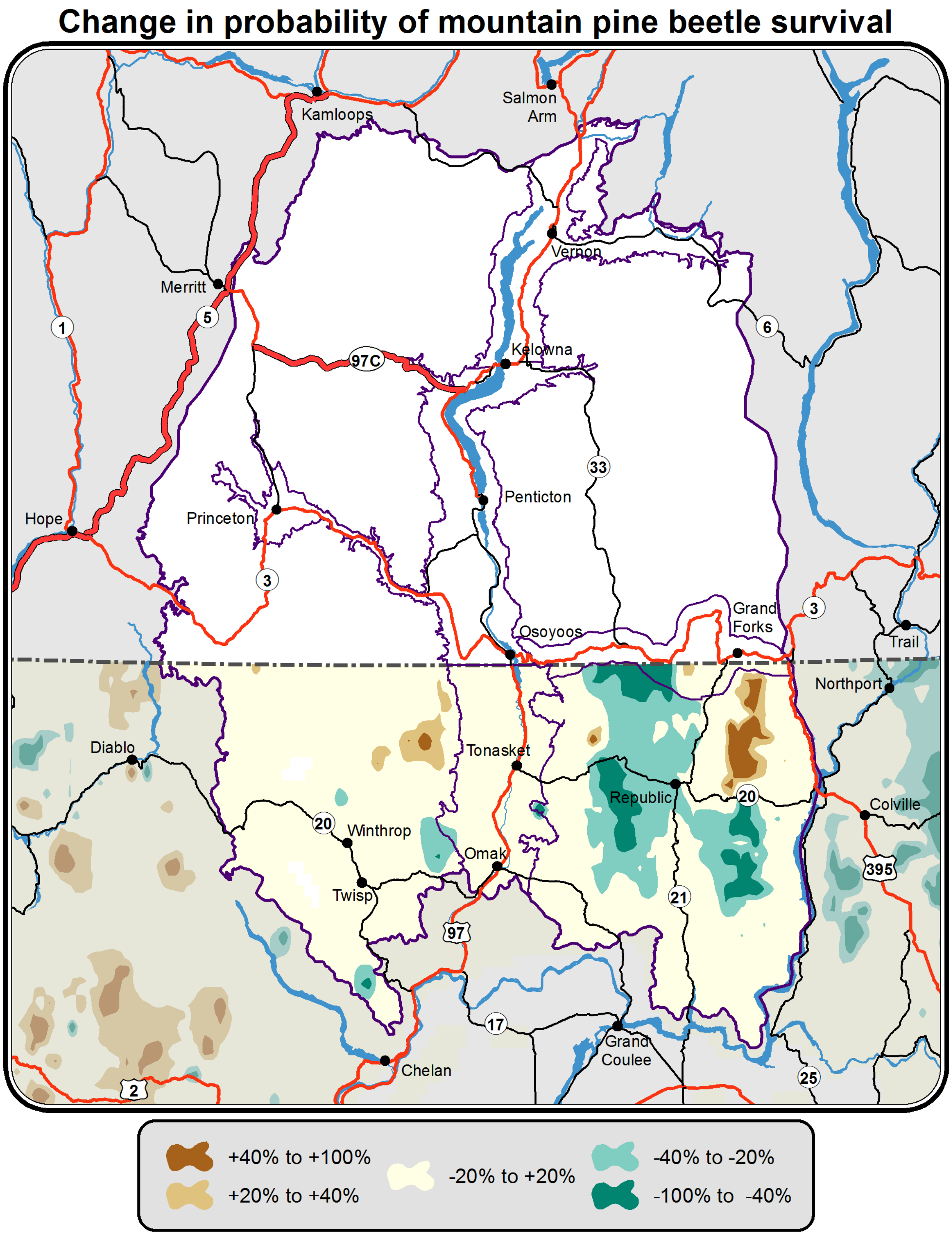
Appendix G.5. Probability of Mountain Pine Beetle Survival

i) Extent: Okanagan Nation Territory



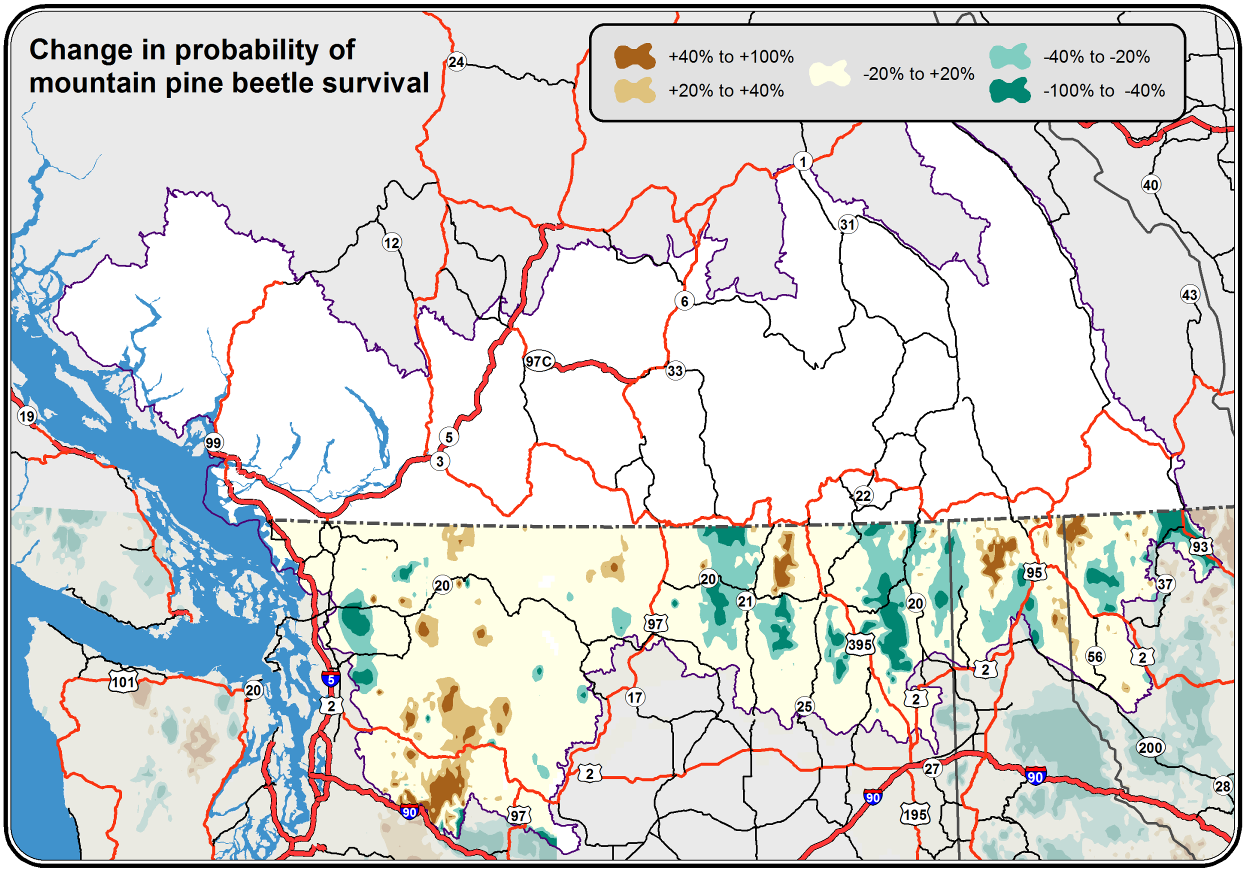
Appendix G.5. Probability of Mountain Pine Beetle Survival

ii) Extent: Okanagan-Kettle Region



Appendix G.5. Probability of Mountain Pine Beetle Survival

iii) Extent: Washington-British Columbia Transboundary Region



Appendix G.6. Projected Changes in Relevant Climate Variables

The following projections of future climate were identified by project partners as being most relevant to understanding and addressing climate impacts on black bear connectivity.[xvii] Future climate projections were gathered from two sources, except where otherwise noted: 1) the Integrated Scenarios of the Pacific Northwest Environment,[8] which is limited to the extent of the Columbia Basin; and the Pacific Climate Impacts Consortium's Regional Analysis Tool,[9] which spans the full transboundary region. For many climatic variables, noticeable differences in the magnitude of future changes can be seen at the US-Canada border; this artifact results from differences on either side of the border in the number of weather stations, the way temperature and precipitation were measured, and differences in the approach used to process these data to produce gridded estimates of daily weather variations.

a) **Water Deficit, July-September.** This map shows the projected change, in percent, in water deficit. Water deficit is defined as the difference between potential evapotranspiration (PET) and actual evapotranspiration (AET), PET - AET. A positive value for PET – AET means that atmospheric demand for water is greater than the actual supply available.

b) **Soil Moisture, July-September.** This map shows the projected change, in percent, in summer soil moisture. Projected changes in soil moisture are depicted by the brown to green shading.

c) **Days with High Fire Risk** (Energy Release Component, ERC > 95th percentile).[xviii] This map shows the projected change in the number of days when the ERC – a commonly used metric to project the potential and risk of wildfire – is greater than the historical 95th percentile among all daily values.

d) **Spring (April 1st) Snowpack.** This map snows the percent change in snow water equivalent (SWE) on April 1st. April 1st is the approximate current timing of peak annual snowpack in Northwest mountains. SWE is a measure of the total amount of water contained in the snowpack. Projected decreases in SWE are depicted by the yellow to red shading.

e) **Length of Snow Season.** This map shows the projected change in the length of the snow season, defined as the number of days between the first and last days of the season with at least 10% of annual maximum snow water equivalent. Projected changes in snow season length are depicted by the yellow to red shading.

f) **Evapotranspiration, July-September.** This map shows the percent change in evapotranspiration between July and September. Projected changes in summer evapotranspiration are depicted by the teal to brown shading.

[xvii] All projections but "Days with High Fire Risk" are evaluated for the 2050s (2040-2069) and the 2080s (2070-2099), based on 3 global climate models (a high (CanESM2), median (CNRM-CM5), and low (CCSM4)), under a high greenhouse gas scenario (RCP 8.5). "Days with High Fire Risk" is evaluated for the 2050s, based on 3 global climate models (a high (CanESM2), median (CNRM-CM5), and low (MIROC5)) using the RCP 8.5 (high) emissions scenario.

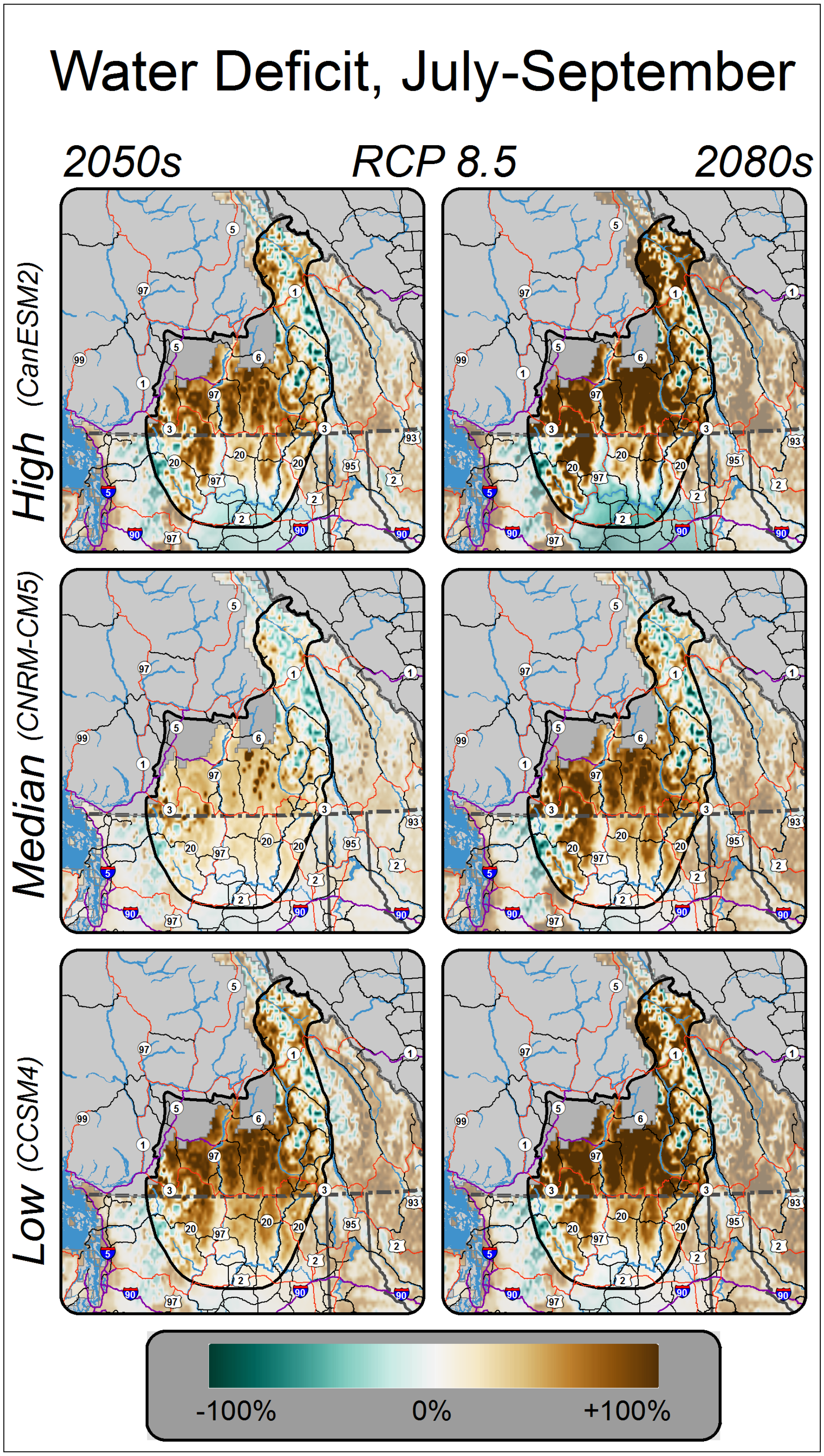
[xviii] Abatzoglou, J.T. 2013. Development of gridded surface meteorological data for ecological applications and modeling. *International Journal of Climatology* 33: 121-131.

g) **Growing Season Length.** This map shows projected change, in percent, in growing season length, defined as the number of days between the first occurrence of at least six consecutive days with daily mean temperature greater than 5 degrees Celsius and the first occurrence after July 1st of at least six consecutive days with daily mean temperatures less than 5 degrees Celsius. Projected changes in growing season length are depicted by the yellow to red shading.

h) **Dry Spell Duration.** This map shows the projected change, in percent, in the maximum number of consecutive days with less than 1 mm of precipitation. Projected change in dry spell duration is depicted by the brown to green shading.

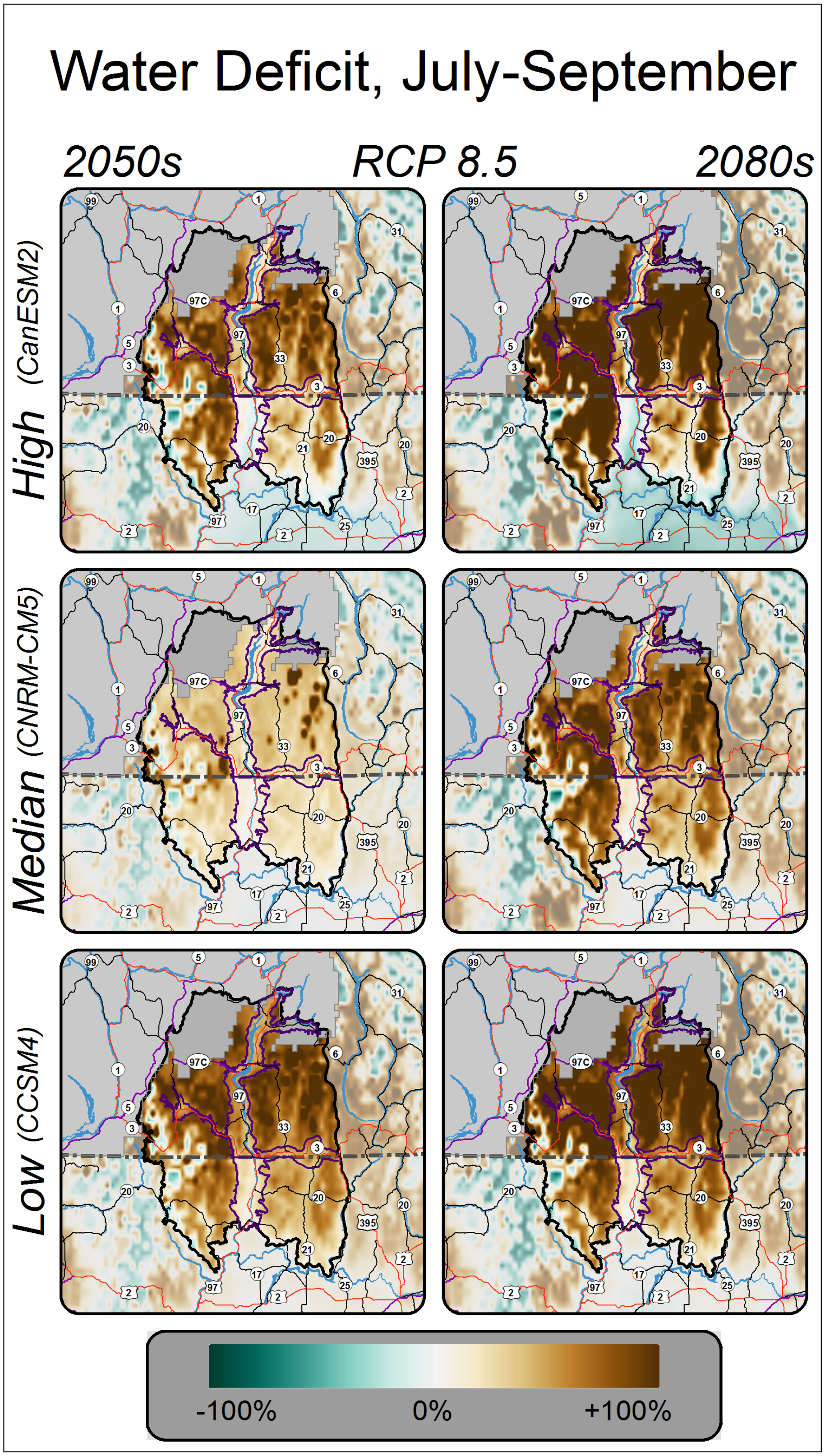
Appendix G.6a. Water Deficit, July-September

i) Extent: Okanagan Nation Territory



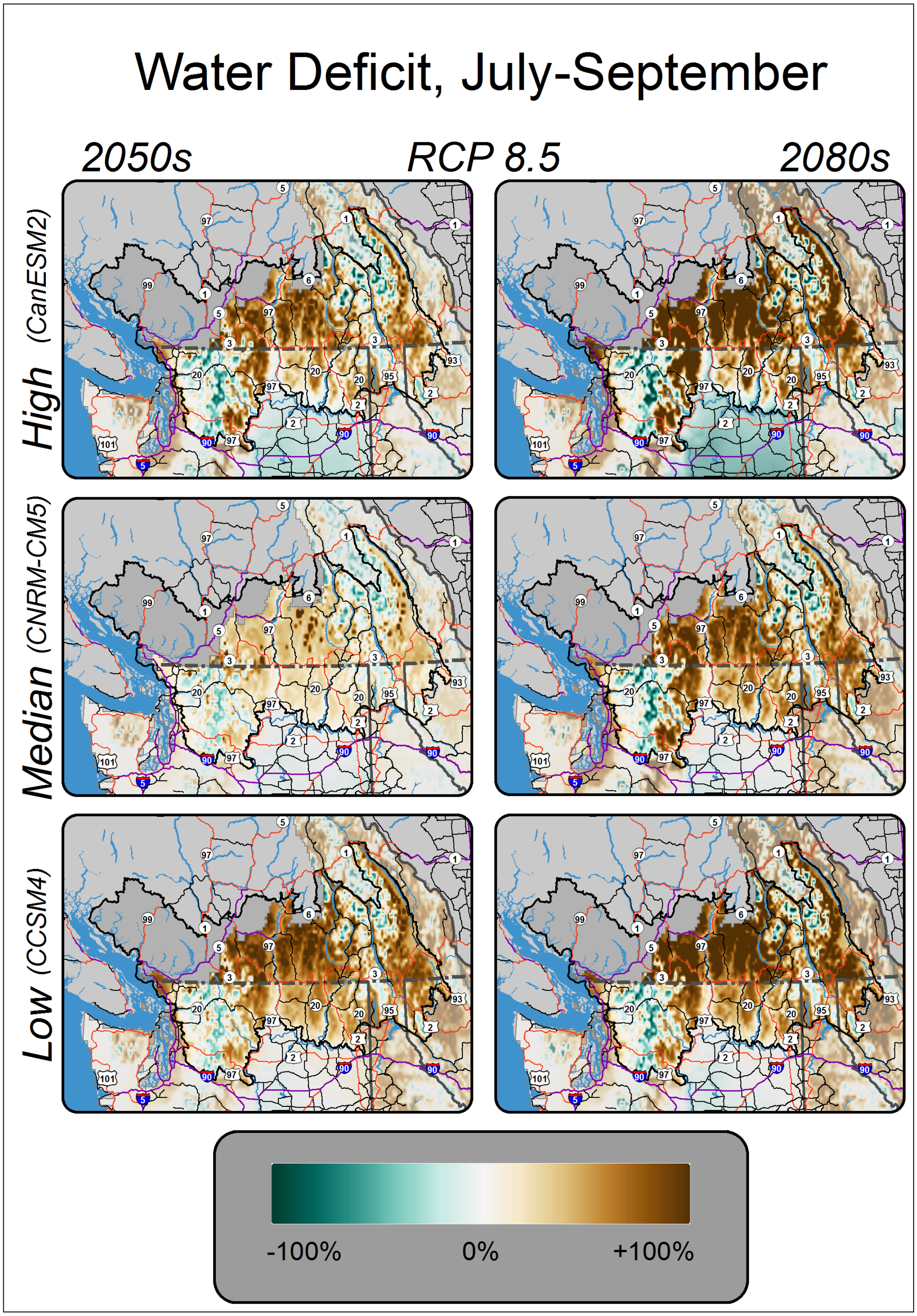
Appendix G.6a. Water Deficit, July-September

ii) Extent: Okanagan-Kettle Region



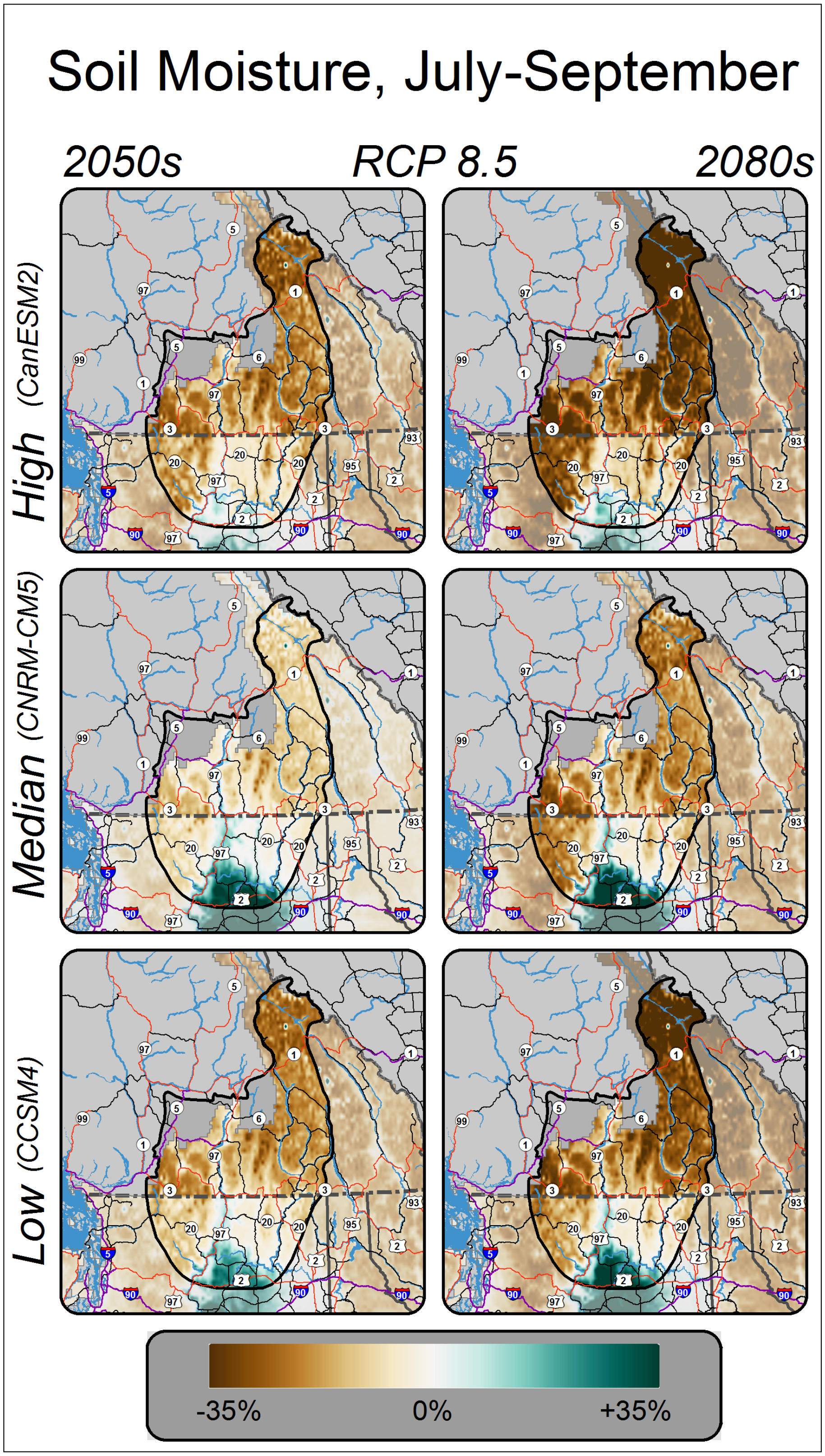
Appendix G.6a. Water Deficit, July-September

iii) Extent: Washington-British Columbia Transboundary Region



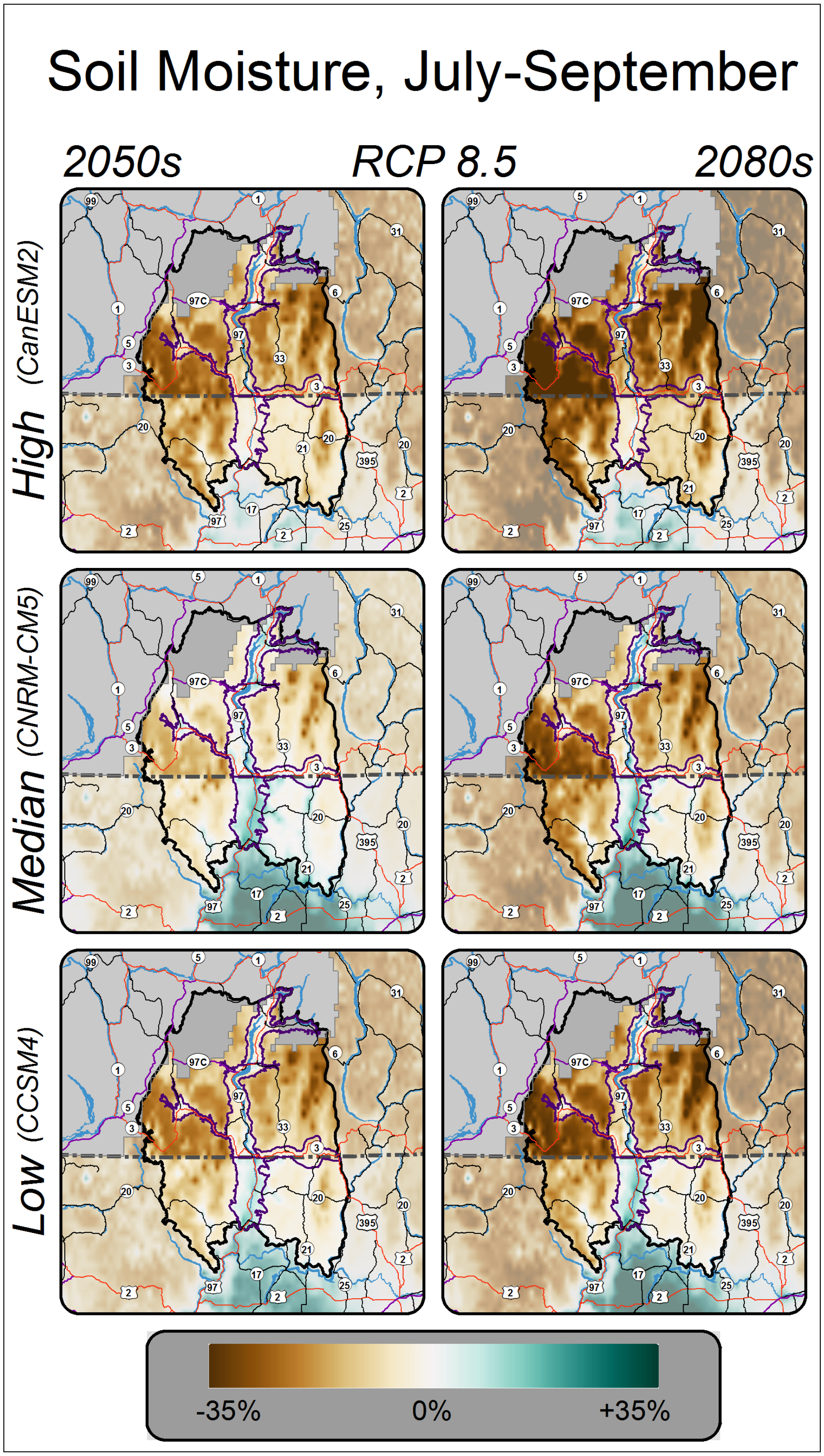
Appendix G.6b. Summer Soil Moisture, July-September

i) Extent: Okanagan Nation Territory



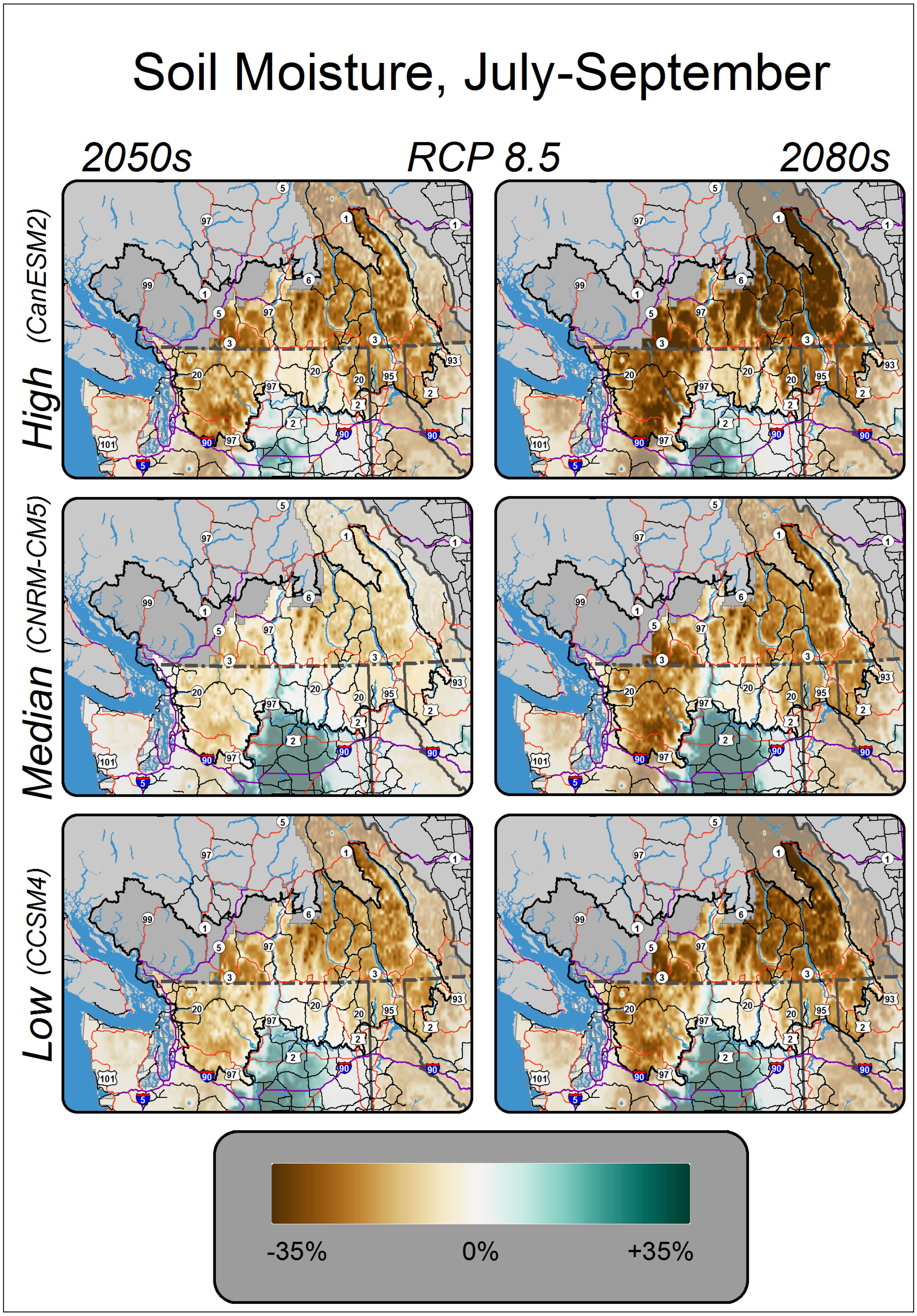
Appendix G.6b. Summer Soil Moisture, July-September

ii) Extent: Okanagan-Kettle Region



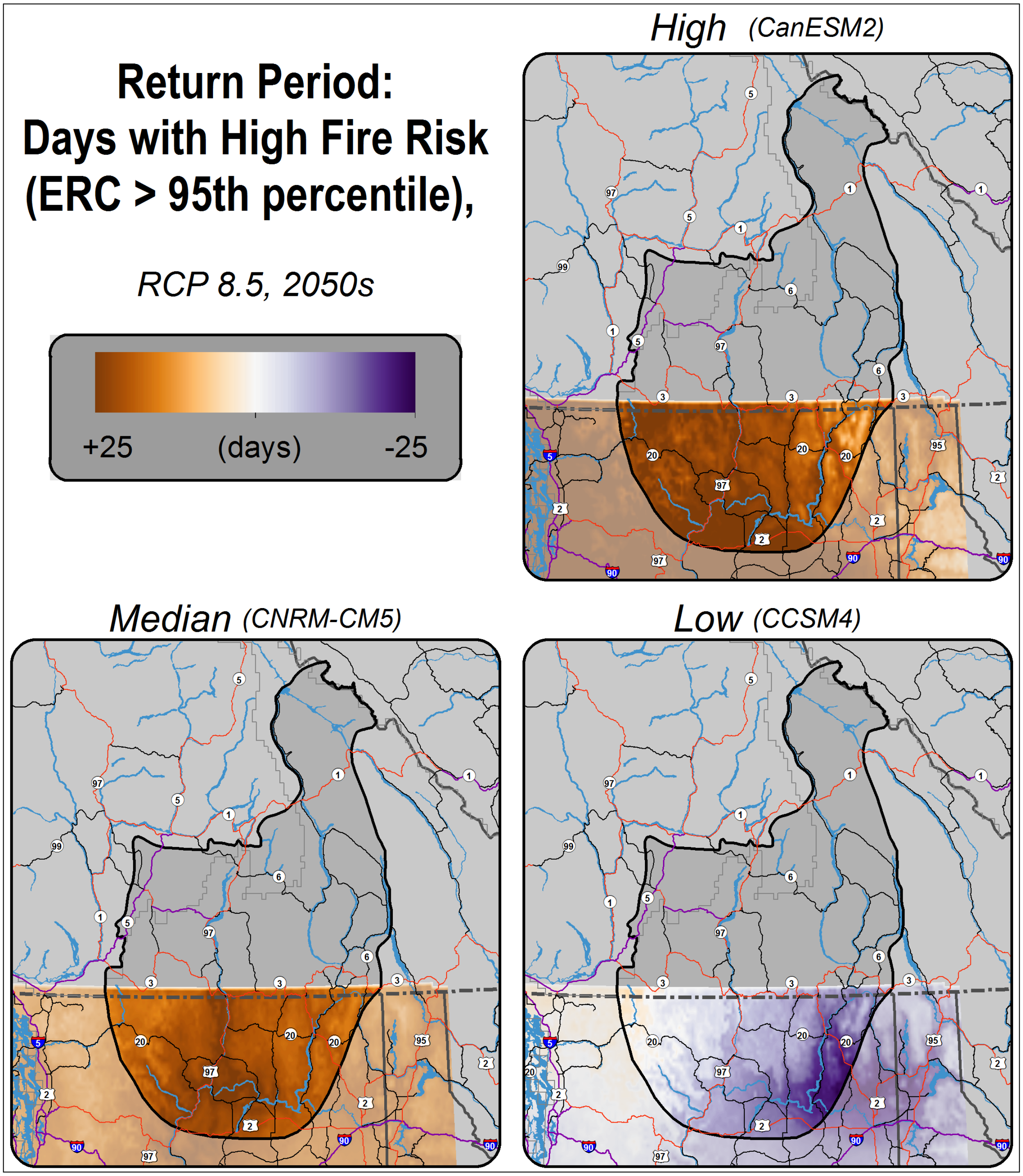
Appendix G.6b. Summer Soil Moisture, July-September

iii) Extent: Washington-British Columbia Transboundary Region



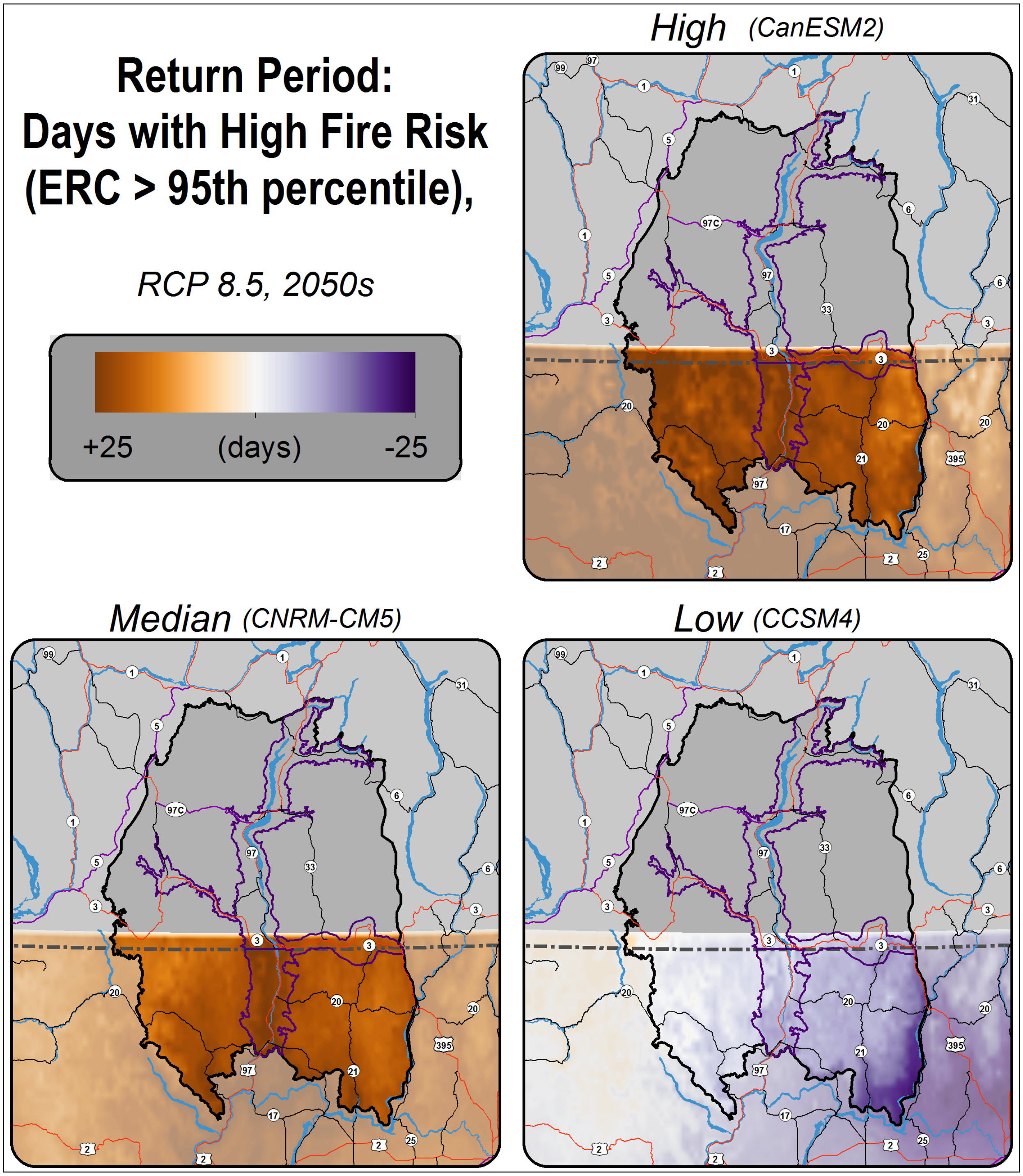
Appendix G.6c. Days with High Fire Risk

i) Extent: Okanagan Nation Territory



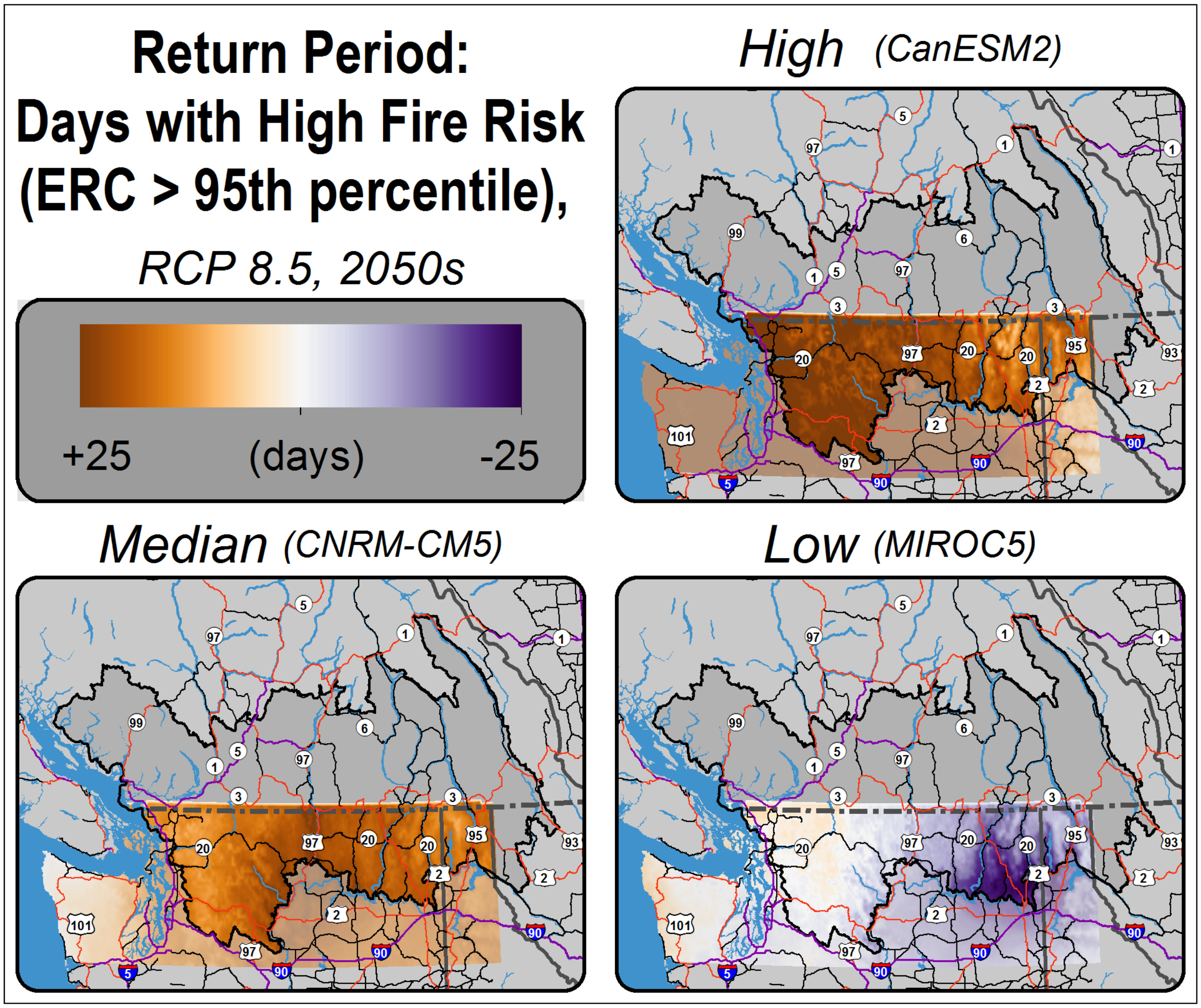
Appendix G.6c. Days with High Fire Risk

ii) Extent: Okanagan-Kettle Region



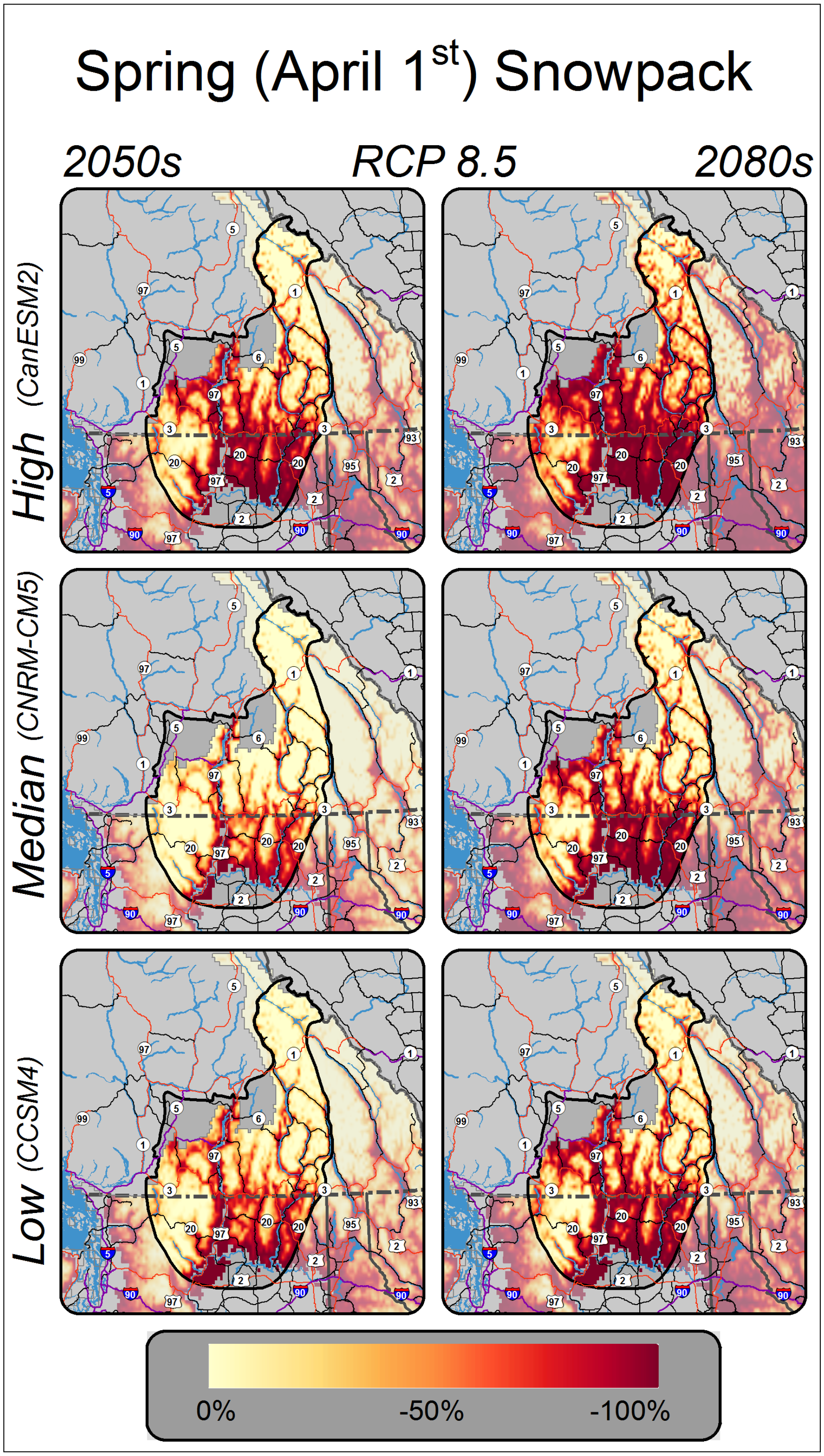
Appendix G.6c. Days with High Fire Risk

iii) Extent: Washington-British Columbia Transboundary Region



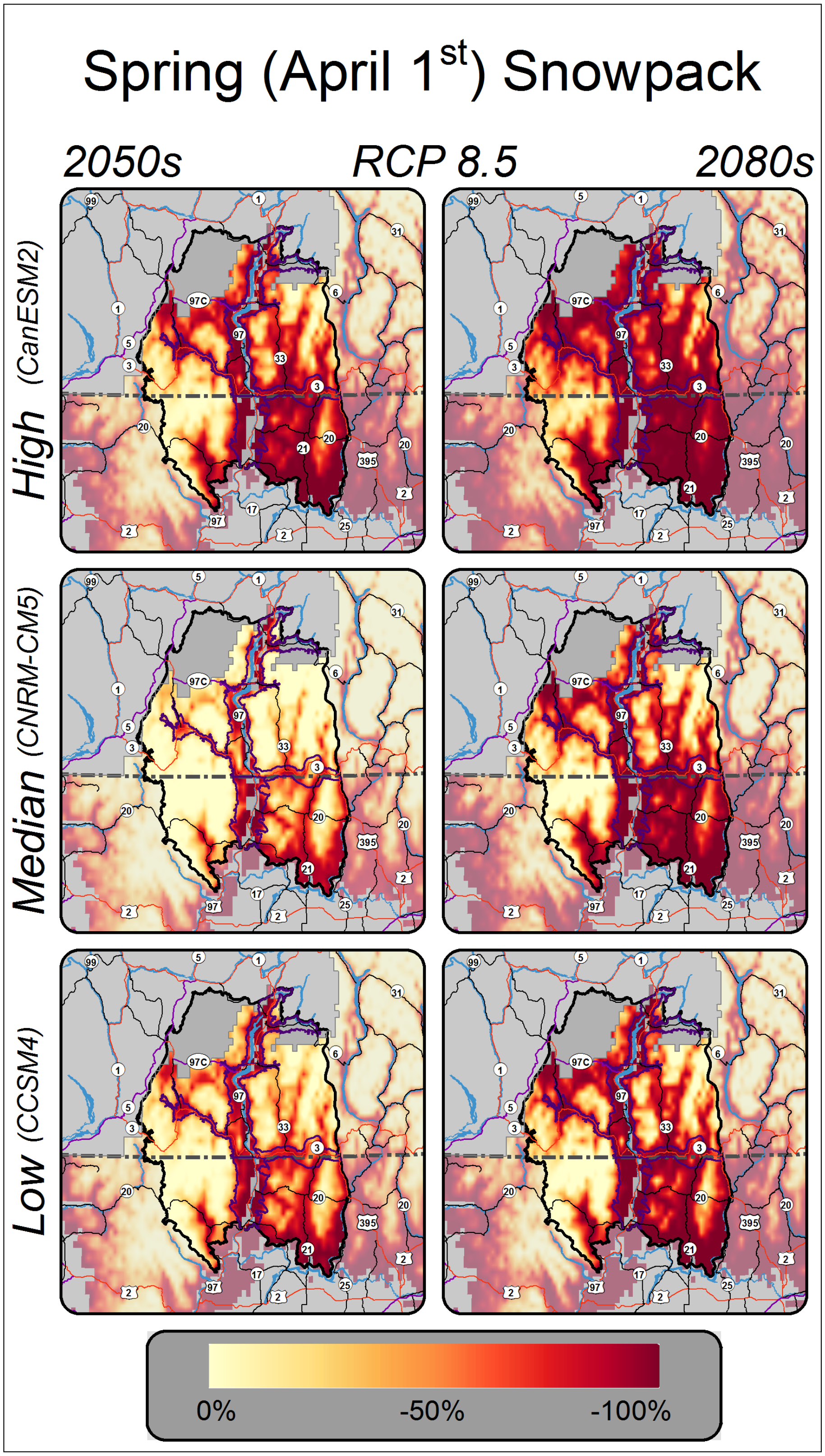
Appendix G.6d. Spring (April 1st) Snowpack

i) Extent: Okanagan Nation Territory



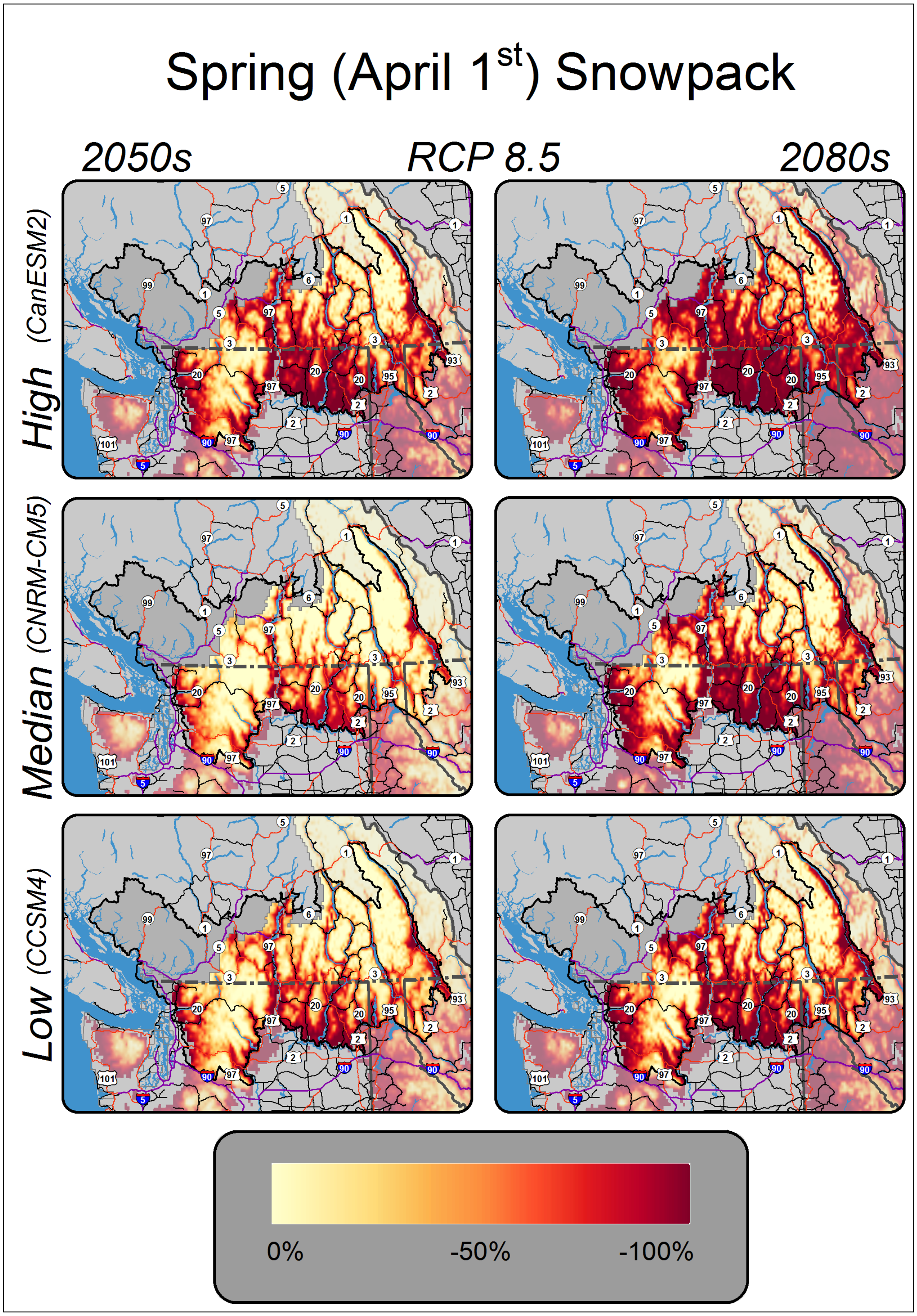
Appendix G.6d. Spring (April 1st) Snowpack

ii) Extent: Okanagan-Kettle Region



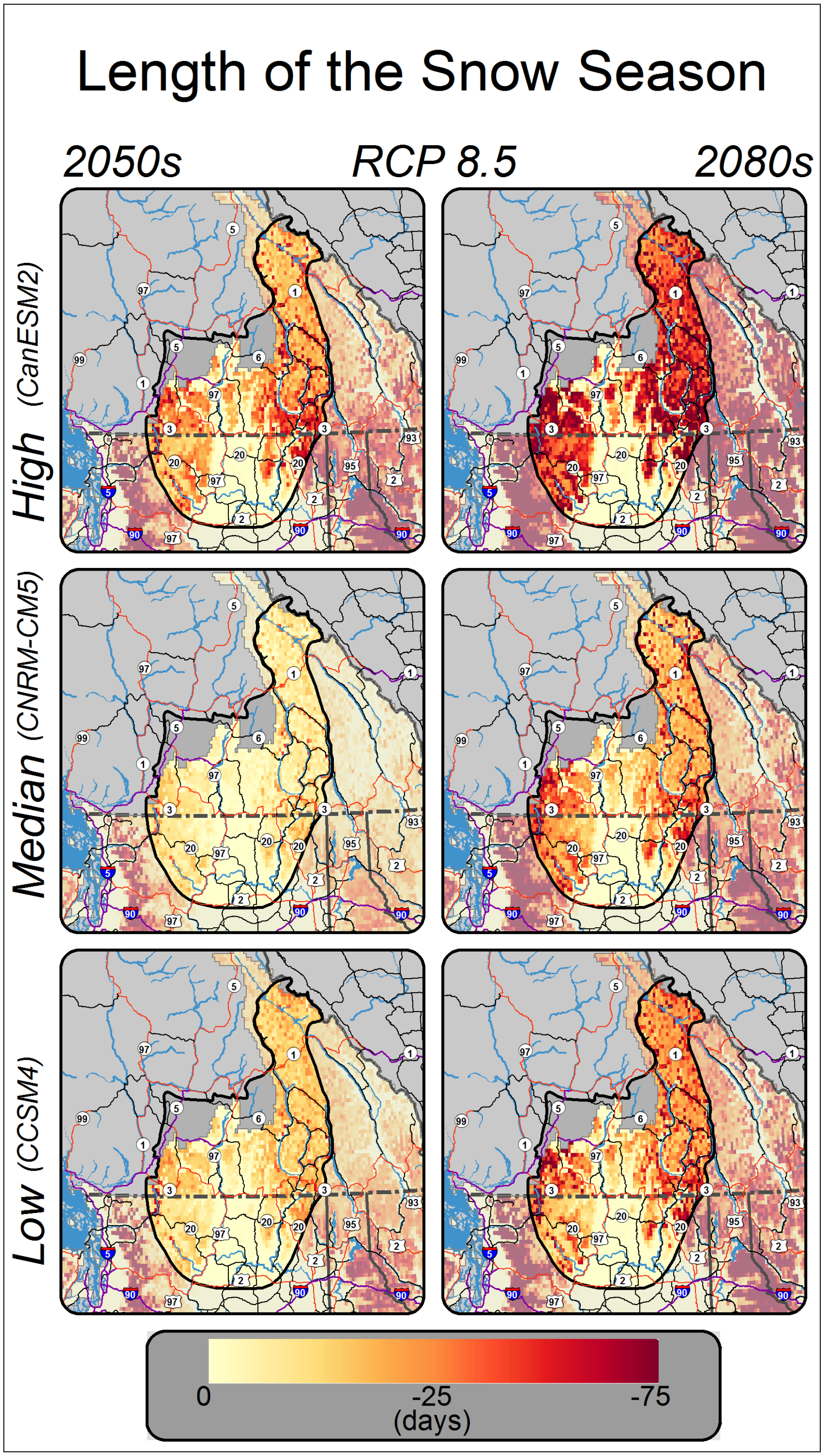
Appendix G.6d. Spring (April 1st) Snowpack

iii) Extent: Washington-British Columbia Transboundary Region



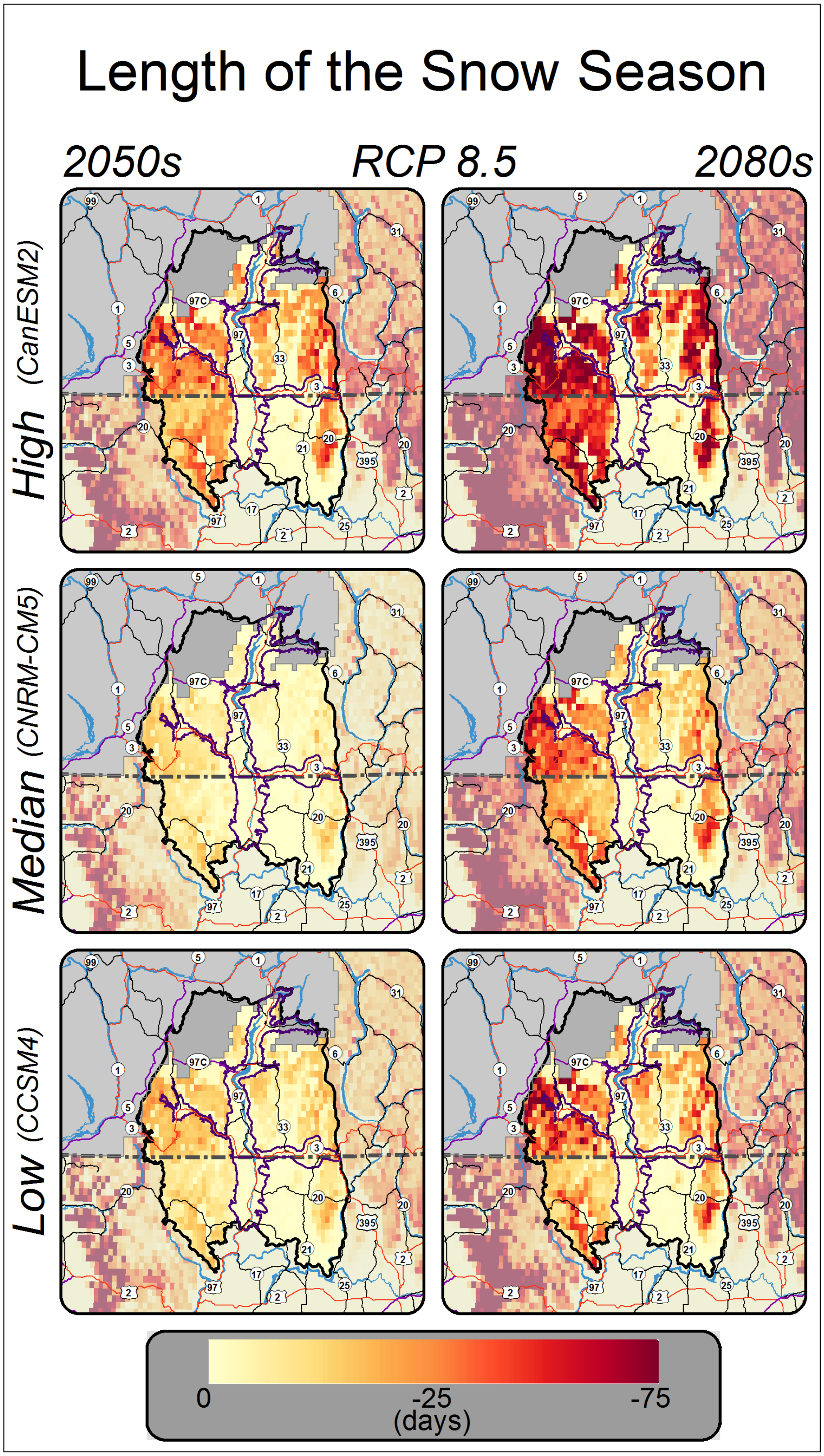
Appendix G.6e. Length of Snow Season

i) Extent: Okanagan Nation Territory



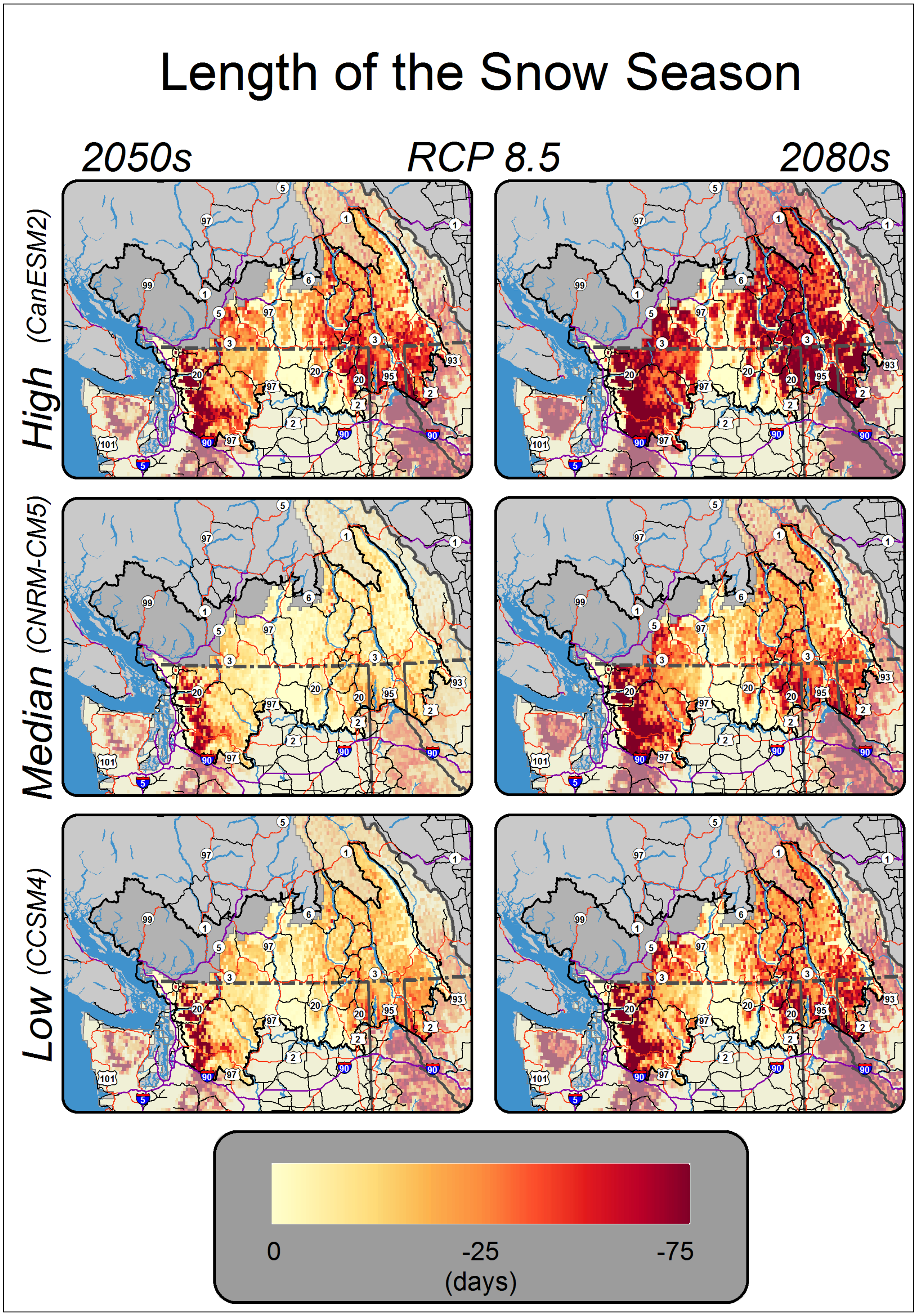
Appendix G.6e. Length of Snow Season

ii) Extent: Okanagan-Kettle Region



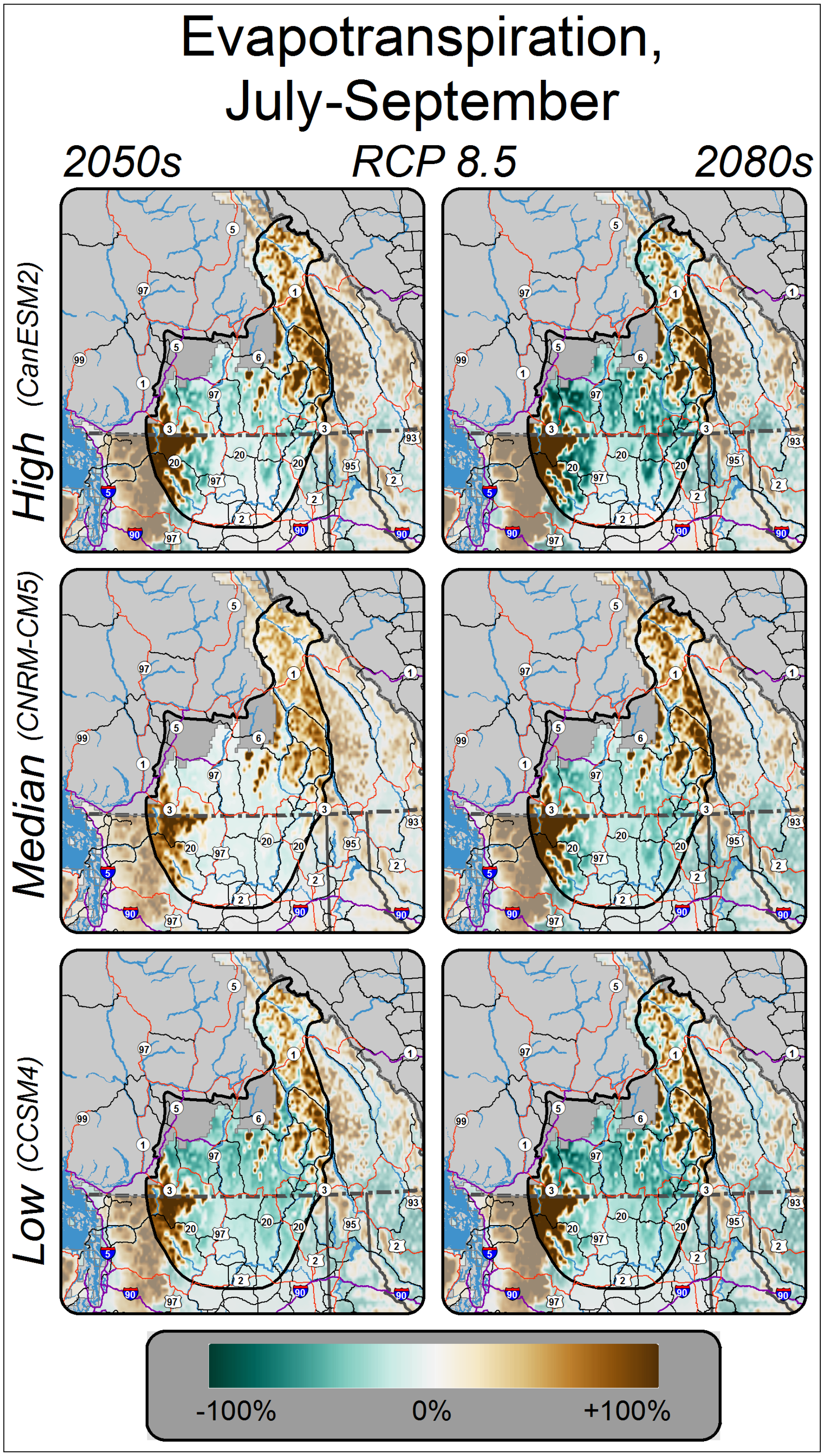
Appendix G.6e. Length of Snow Season

iii) Extent: Washington-British Columbia Transboundary Region



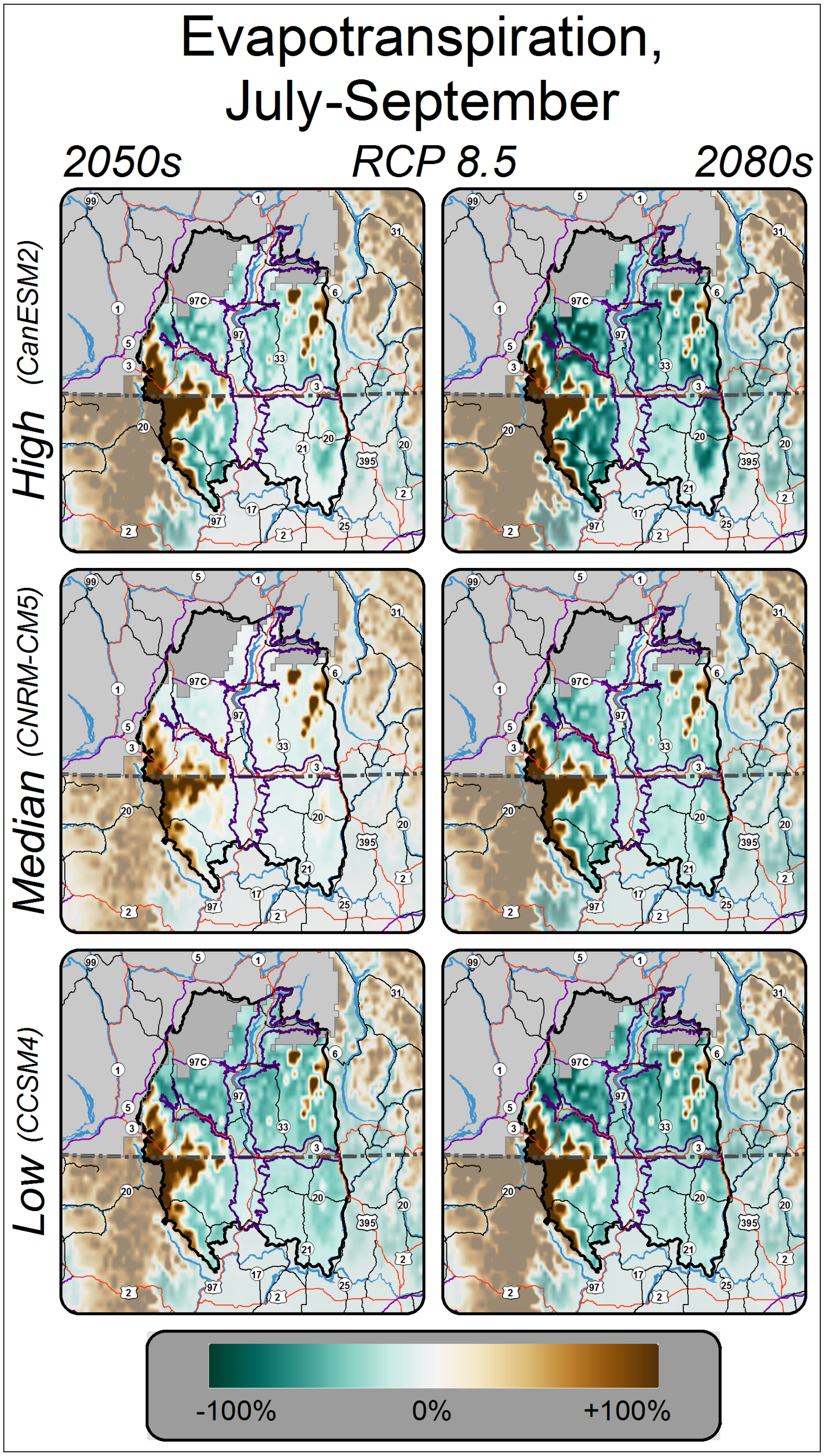
Appendix G.6f. Evapotranspiration, July-September

i) Extent: Okanagan Nation Territory



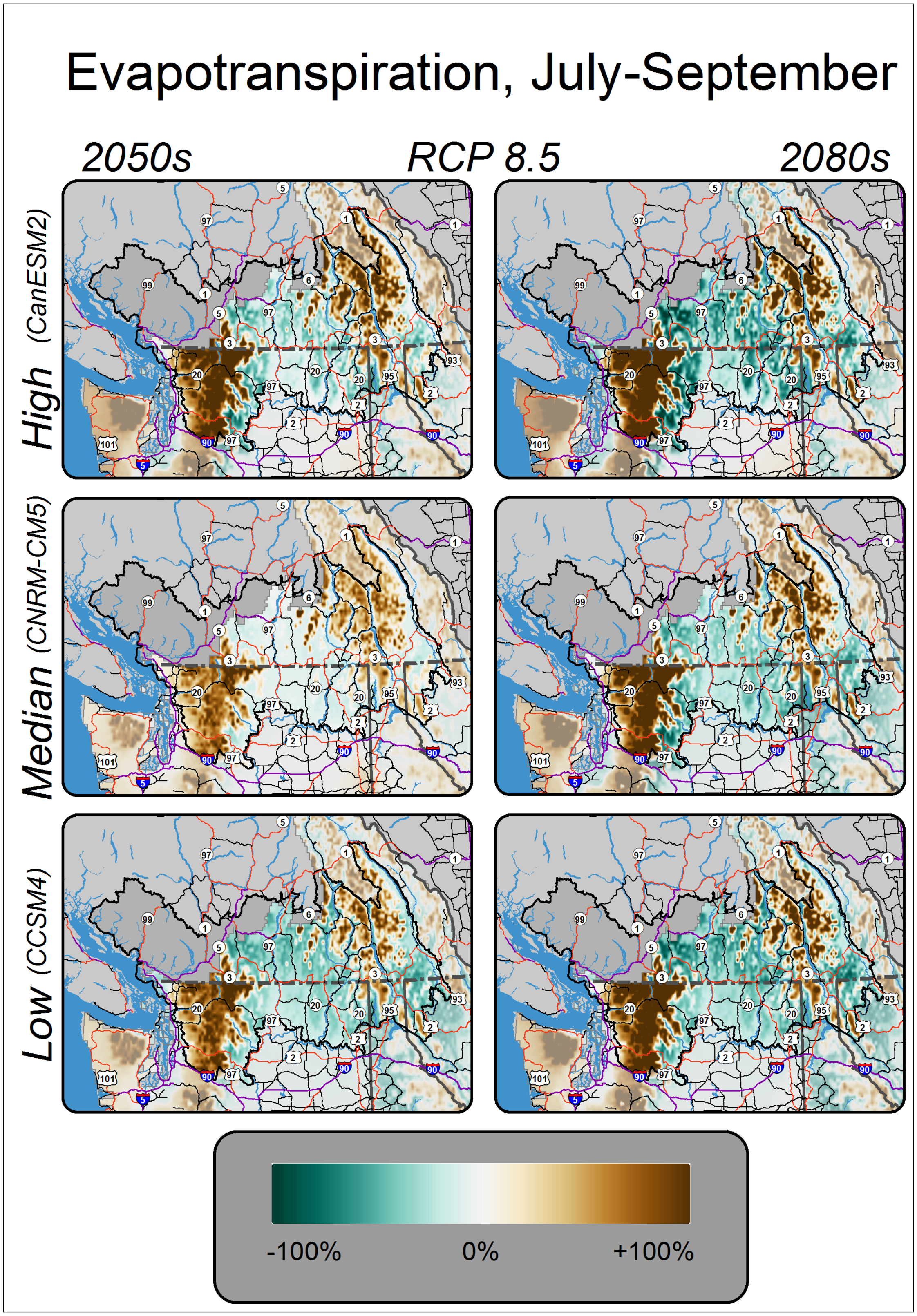
Appendix G.6f. Evapotranspiration, July-September

ii) Extent: Okanagan-Kettle Region



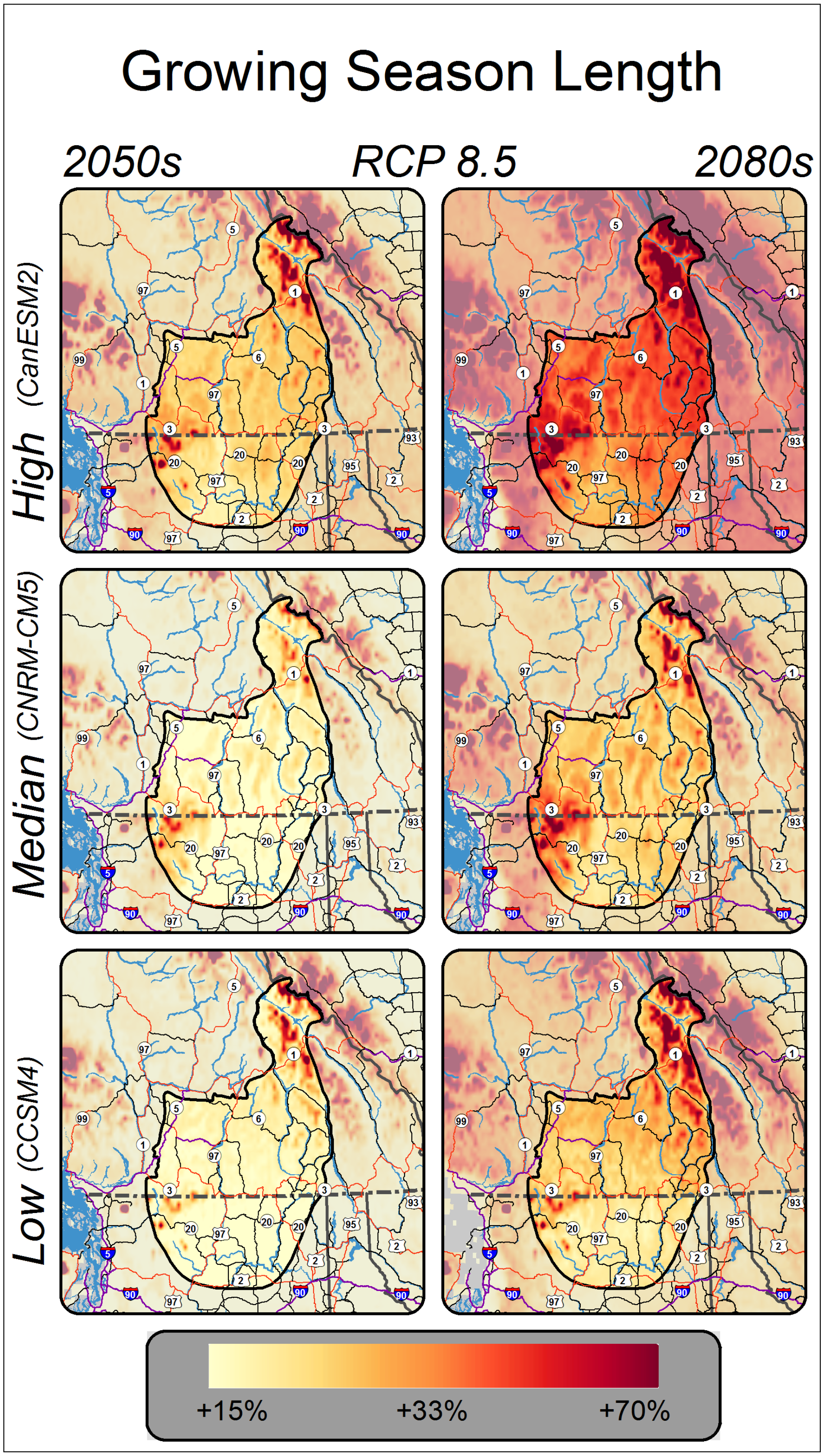
Appendix G.6f. Evapotranspiration, July-September

iii) Extent: Washington-British Columbia Transboundary Region



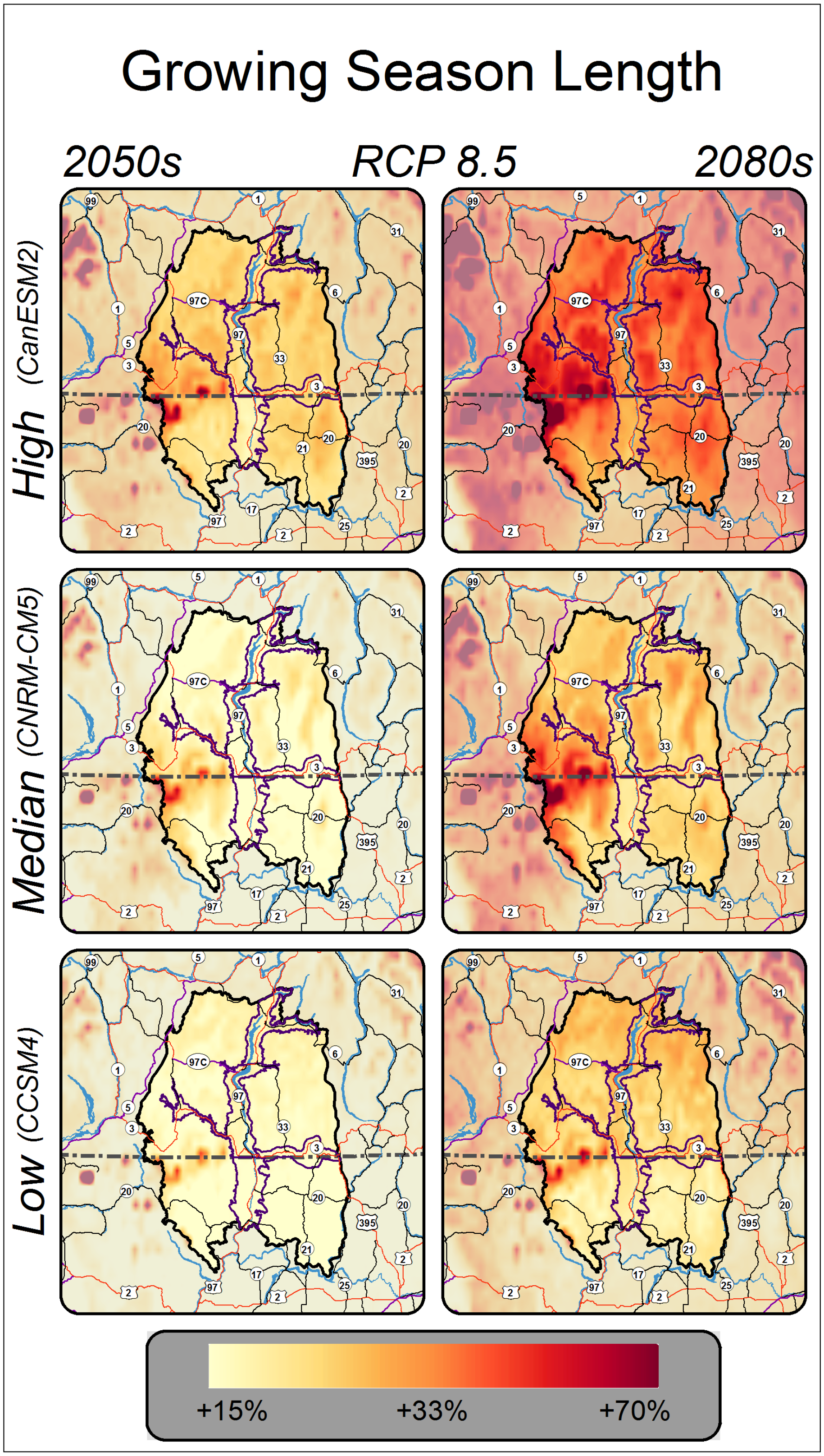
Appendix G.6g. Growing Season Length

i) Extent: Okanagan Nation Territory



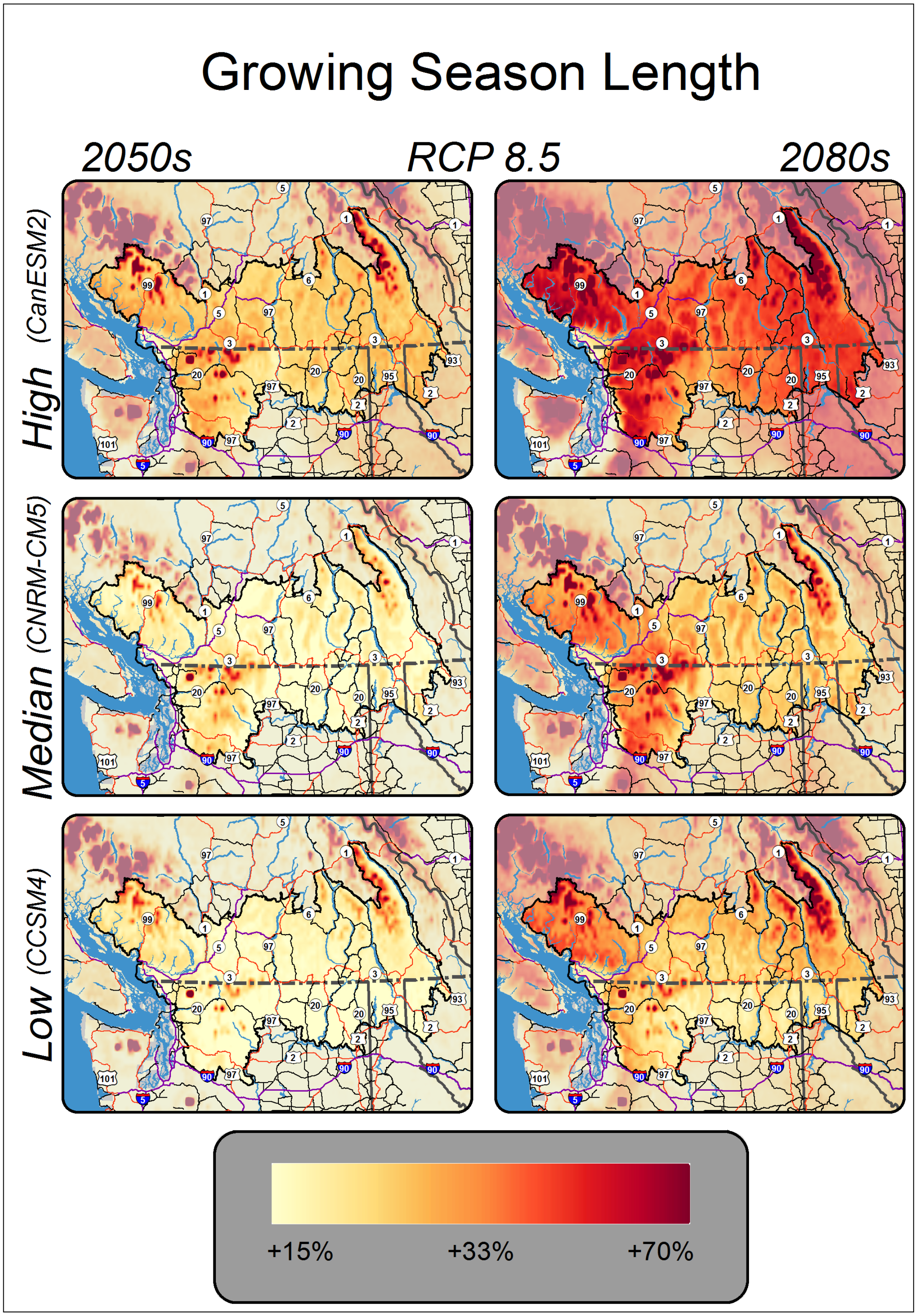
Appendix G.6g. Growing Season Length

ii) Extent: Okanagan-Kettle Region



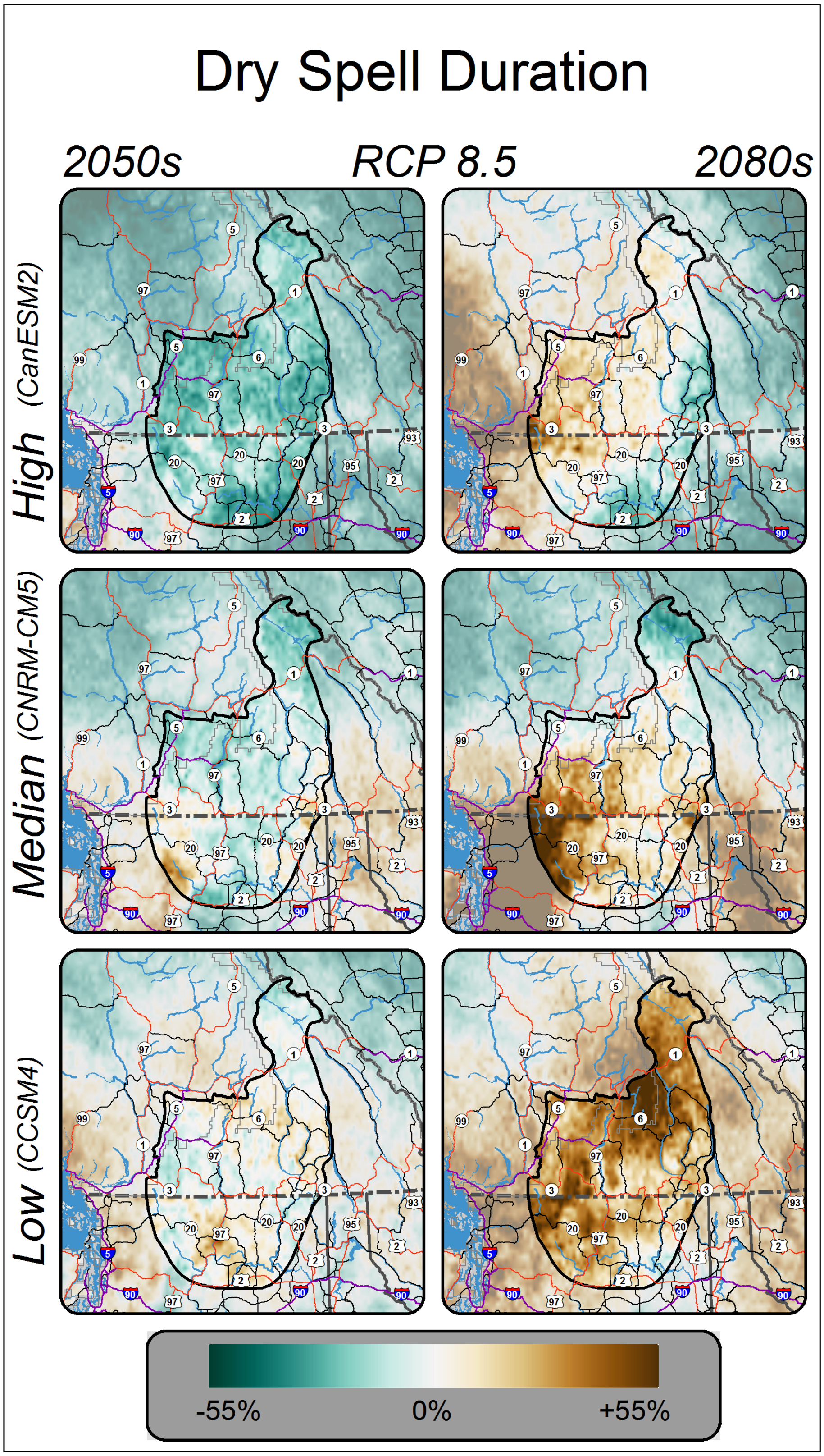
Appendix G.6g. Growing Season Length

iii) Extent: Washington-British Columbia Transboundary Region



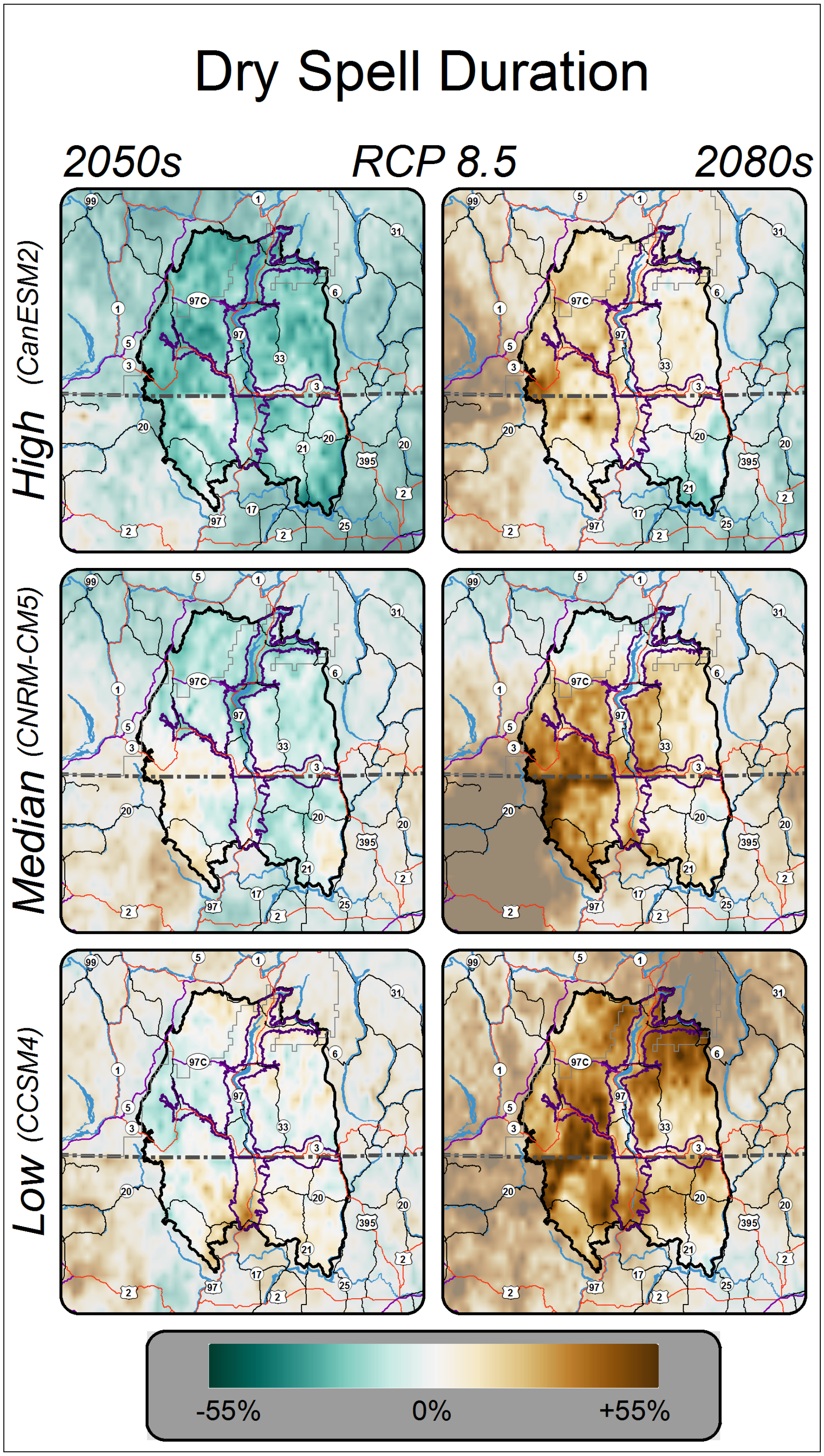
Appendix G.6h. Dry Spell Duration

i) Extent: Okanagan Nation Territory



Appendix G.6h. Dry Spell Duration

ii) Extent: Okanagan-Kettle Region



Appendix G.6h. Dry Spell Duration

iii) Extent: Washington-British Columbia Transboundary Region